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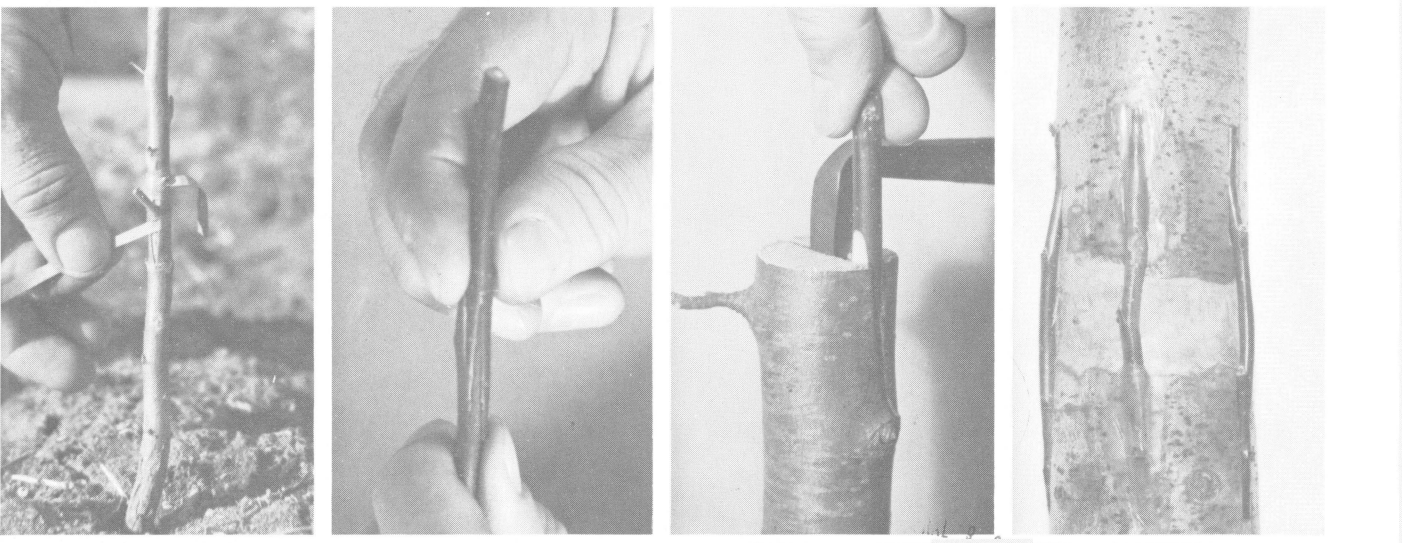

FRUIT TREE PROPAGATION

Cooperative Extension Service
The Ohio State University

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DEFINITION OF TERMS

BUDDING is a method of graftage. It consists of inserting a single leaf bud, the scion, with or without attached bark and wood piece, into the stock by specific techniques. Budding is done in the latter part of the growing season, from late June into September.

BUDLING is used to identify the plant resulting from the first year's growth after budding.

BUDSTICK is the term applied to the current season's growth from which single buds are removed for budding.

CAMBIUM LAYER refers to a single layer of cells between the wood and bark tissues which surrounds all woody portions of a tree. This layer of cells, through cell division, produces two sets of cells that make up the growing tissues on both sides of it. On the outside, the new cells make up what is called phloem. On the inner side, the wood or xylem tissues are formed. The phloem tissues eventually make up the layers of bark. The cambium is thus the source of all growth in thickness of the woody stem. In graftage, the cambium of the scion must line up with the cambium of the stock as perfectly as possible if a good union is to result.

CLONE (or clon) is a horticultural term used to denote a specific cultivar that has been propagated asexually or vegetatively. A number of specific rootstocks used in fruit tree propagation that are so propagated are called clonal rootstocks.

CUTTINGS are sections of plant stems, leaves, buds, or roots that have been rooted after proper insertion in sand, soil, or other suitable media.

CULTIVAR is the term now used in place of "variety" which was common in horticultural literature for many years. Cultivar, to be used to designate horticultural varieties throughout the world, was adopted by the International Code of Nomenclature for Cultivated Plants in 1961. The term is being widely used in Europe and is now beginning to be used generally in the United States. Throughout this bulletin the term, cultivar, replaces the former term, variety.

GRAFTAGE is the term applied to the methods of inserting a section of one plant, the scion, into another, the stock. A grafted tree thus consists of at least two parts, the root system of the stock and the scion cultivar or top.

GRAFTING is a term in common usage that refers to certain techniques of inserting a section of stem with leaf buds (the scion) in the stock. Several different procedures may be employed in grafting techniques. Dormant scions are used; therefore, grafting is done in early spring, usually before growth begins.

INTERSTOCK or **INTERMEDIATE STOCK** refers to a section of trunk or the basic framework which is introduced between the rootstock and the scion cultivar. An interstock is chosen for specific vegetative characteristics or for the effects it may produce upon tree size. Interstocks may be used to develop desirable framework characteristics, such as winter hardiness or disease resistance, and to make possible the joining of two cultivars which are incompatible if grafted directly. Thus, such trees consist of three distinct parts: the rootstock, the interstock, and the scion cultivar.

MOUND LAYERING is a term used to denote a method of vegetative propagation. An individual plant may be layered, or plants may be lined out in rows for layering. First, the top of each plant is cut back. As shoots develop from the basal part of the stem, soil or some other rooting medium is hilled or mounded over the base of the shoots, without completely covering the new growth. Plant species and cultivars that can be successfully layered will form roots on the portion of the stem or shoot below the soil surface. The rooted shoots may be removed later and used as rootstocks for budding and grafting.

ROOTSTOCK is the term applied to that part of a tree which makes up the root system of a grafted or budded tree.

SCION denotes a short piece of twig or only a bud with attached section of bark which is inserted into the stock.

SEEDLING refers to the plant that has grown from a seed.

STOCK is a term used to identify a plant or part of a plant upon which a scion cultivar is grafted or budded.

STOOL or **STOOL BED** is used to designate a plant or group of plants of a specific clone or cultivar of rootstock which is to be multiplied by mound layering.

TOP WORKING refers to the practice of changing the top of a tree from one cultivar to another through the use of budding or grafting methods.

VARIETAS is the term now used to designate a "botanical variety," and to differentiate it from the "cultivar" or "cultivated variety." It is used by botanists when they refer to two or more varieties of a species which have originated in natural populations of the world and have been maintained as distinct natural variants of the parent species. Varietas may have their own geographical distribution.

VARIETY is the term that was used for many years to denote a cultivated variety of plant. It is being replaced by the term "cultivar" in horticultural literature, as explained under the definition previously given.

WATERSPROUT is the term applied to a vigorously growing unbranched shoot of the current season. It is generally growing in an upright position, and may arise from a primary scaffold branch or smaller branch, often adjacent to a pruning wound.

Fruit Tree Propagation

Plant propagation methods can be useful and profitable to the modern fruit grower as he considers planting a new tree fruit "CULTIVAR" (this new term is defined on page 4). He can produce his own planting stock by combining desired new cultivars with size-controlling or other specialized rootstocks. Such combinations are often not available commercially. On the other hand, he may use these methods to change the established planting of a cultivar to a new one through the use of propagating techniques.

Commercial plant propagators constantly search for improved rootstocks and cultivars, and techniques for reproducing both. Changes are continually taking place in fruit tree cultivars, in rootstocks for specific purposes, and in the specific techniques of their propagation. The propagator must keep abreast of the changes if he is to continue supplying the trade with the best and most suitable planting stock for today's fruit plantings.

The amateur horticulturist will find that the use of propagating procedures and techniques can add an interesting and exciting phase to his avocation. New combinations of cultivars and plant species are at his disposal for home experimentation. He can change a tree from one cultivar to another, or through the use of certain techniques can have several cultivars growing on one tree.

The successful production of fruits depends, first, on the choice of the suitable cultivar for the purpose intended. Also of importance is the desirability, uniformity, and consistent productivity of the plant on which the fruits are grown. These considerations are involved in fruit tree propagation.

Cultivars of fruits do not "come true" from seed. Thus, if five seeds of a Jonathan apple are planted, each will produce a tree bearing fruit somewhat different from the others, and none may closely resemble Jonathan. For this reason, it is necessary to propagate fruit cultivars by methods other than seeds, by asexual or vegetative means.

A number of vegetative methods have been developed for use with horticultural plants. In the case of fruit trees, budding and grafting are the most important methods of propagating desired cultivars. In the case of certain rootstocks, other vegetative methods may be employed such as the rooting of cuttings (stem, leaf or root), layering of stems or other above-ground parts or using suckers that grow from roots. Many rootstocks are produced directly from seed, but their seedlings often produce wide variability in individual tree characteristics.

Few cultivars of tree fruits can be successfully propagated by either hardwood or softwood cuttings, or by layering above-ground parts of the plant. It is impractical to use suckers from the roots or underground stems of commercially propagated fruit trees, since the root system is different from the cultivar that is growing above ground for its fruit.

In the following pages, the reader will find detailed information on the propagation of seedling and clonal rootstocks as well as descriptions of budding and grafting procedures used in propagating tree fruit cultivars.

ROOTSTOCK CONSIDERATION

Rootstocks (for propagation of cultivars) may be purchased from some nurseries or propagators. However, the grower may wish to produce his own from a selected source of seed or from clonal stocks.

Seedling rootstocks are produced from the seed of a given species or cultivar. Rootstocks may be produced from certain cultivars or clones by vegetative means, such as mound layering of the East Malling and Malling-Merton colonal selections used for controlling the size of apple trees. Some of the clonal rootstocks may be propagated by hardwood cuttings.

COMPATIBILITY AND INCOMPATIBILITY

A stock and scion are considered to be compatible when a complete and satisfactory union of the two plant parts develops following a method of graftage. Not only must the union be complete, but the tree must grow and perform satisfactorily for an indefinite period of time if the combination is to be commercially valuable.

Incompatibility, then, may be defined as the failure of a stock and scion to develop complete union

following graftage. Likewise, the failure of grafted trees to perform satisfactorily may be due to a degree of incompatibility. Thus, incompatibility may appear as a complete lack of union between stock and scion, or it may be only partial incompatibility, resulting in poor performance of the tree.

There is no way of predicting the state of compatibility that may exist in a stock-scion combination that has not been previously tried. The trial and error method must still be used to determine the compatibility of any new stock-scion combination. Experiences of trial and error comprise the body of information on the subject of compatibility.

It is conceivable that all cultivars within a species, such as the peach, would be compatible with each other. This is generally true, but there are exceptions. Likewise, it is thought that closely-related species should be compatible, such as the peach *(Prunus persica)* and the European plum *(Prunus domestica)*, but this is not always true. Stock-scion compatibilities are discussed in the various sections of this bulletin concerned with specific fruits.

SELECTION OF SEEDLING ROOTSTOCKS

Apples — Seeds from the cultivars Delicious, Rome Beauty, Winesap, Golden Delicious, and Jonathan have given the best results in producing seedlings for apple cultivar propagation. The triploid cultivars, such as Baldwin, Rhode Island Greening, Gravenstein, Stayman, and Turley are unsatisfactory for producing seedlings, primarily because of poor seed germination.

Pears — Seed of the Bartlett cultivar is most widely used for producing seedlings on which standard pear cultivars are propagated. Winter Nelis and Beurre Hardy are also satisfactory seed sources.

Certain oriental pear species *(Pyrus calleryana, P. serotina and P. ussuriensis)* show greater resistance to fire blight than do cultivars of common pears. Some have been tried as blight-resistant rootstocks, but most have failed to perform satisfactorily.

Quinces — Seed of the common cultivars of quince are used as rootstocks for propagating this fruit. The Angers Quince East Malling Type A may also be used for propagating cultivated cultivars.

Apricots — Seedlings grown from seeds of common cultivars of apricots are preferred. Seedlings of the Myrobalan plum *(Prunus cerasifera)* may also be used and produce satisfactory trees under most conditions.

Cherries — Two different rootstocks are in common use for propagating cherry trees. Mazzard, or wild sweet cherry, *(Prunus avium)* is the most widely used and best adapted rootstock for sweet cherry cultivars. Mahaleb cherry *(Prunus Mahaleb)* is the preferred rootstock for red tart cultivars, such as Montmorency.

Advantages of Mazzard as a rootstock lie in its ability to produce larger, long-lived trees and in its compatability with a wide variety of sweet cherry cultivars. Mazzard roots will tolerate slightly less well-drained soils, but will perform best on soils with good internal drainage.

Mahaleb rootstocks are more winter hardy and more drought resistant than Mazzard, but do require a well-drained soil. Cultivars on this stock tend to come into bearing earlier than on Mazzard. Selection of rootstocks, however, cannot replace planting on well-drained sites.

Virus diseases, such as cherry yellows and necrotic ring spot, are present in most trees of both the Mahaleb and Mazzard species. These diseases are among the few viruses that can be transmitted through the seeds. Thus, it is important to obtain seed from trees that are known to be free of the major virus diseases. Seeds of virus-infected trees will produce many virus-infected seedlings. When used as rootstocks, these in turn infect the cultivar budded on them.

Peaches and Nectarines — Seeds of common peach cultivars, such as Redhaven, Halehaven, Elberta, and Belle of Georgia produce satisfactory seedlings on which to bud these fruits. In nursery propagation, seed of the Lovell peach, a California cling, has been widely used. Certain selections of red-leaved peach cultivars have found wide use in recent years. If buds do not unite with these rootstocks, the stock growth can be readily distinguished from growth of a cultivar since shoots from the rootstock will have red leaves. Some selections of the red-leaved peaches may produce trees that are weak and small due to incompatibilities between the rootstock and the scion cultivar.

Plums and Prunes — The most widely used rootstock for these fruits is the Myrobalan or cherry plum *(Prunus cerasifera)*. Seedling trees in California and other states constitutes the largest source of Myrobalan seed supply. Seeds from domestic cultivars, such as Stanley, Italian Prune, Green Gage, and French Prune, can be used, but are much less satisfactory than Myrobalan.

Myrobalan seedlings frequently show a leaf spotting called "chlorotic fleck." Affected seedlings are smaller than normal ones, as are trees budded on them, and should not be used in propagation of any plum cultivars. The Stanley cultivar is particularly susceptible to this difficulty, and develops a constriction at the bud union when budded on infected seedlings of Myroban. Trees so affected are weak and short-lived. The causal factor, which may be a virus, is carried in the seed and transmitted to susceptible cultivars propagated on that stock.

There are certain strains of Myrobalan plum that are now believed to be free from virus, but are not yet readily available from nurseries or seedling propagators. If sources of these strains can be found, they should be used. Two strains, Myrobalan 29 C

and Ohio 2 (C2), have proved to be completely compatible with the Stanley and several other cultivars. This indicates that these two strains are possibly virus free. These have been widely tested and are maintained in the virus free collection at Prosser, Washington.

PRODUCTION OF SEEDLINGS

Seeds for the production of seedling rootstocks should be taken from ripe fruits or obtained from a reliable source. The problems of virus diseases and compatibility between fruit cultivars and rootstock selections make it necessary for the fruit tree propagator to obtain seeds from known healthy trees or from a reliable seed supplier.

Three conditions important in producing desirable fruit tree seedlings are: (1) seeds properly conditioned before planting, (2) a well-drained planting site with soil of good tilth and fertility, and (3) seedling rows kept weed-free throughout the growing season.

Conditioning of Seeds

Seeds of tree fruits, like many others, will not germinate when planted directly from the mature fruits. It is first necessary for the seeds to complete a period of "after-ripening." During this period a series of chemical changes and embryo development essential to germination, takes place within the seeds.

These changes can be completed only if the seeds are stored between 33° and 45° F. under moist conditions for a certain length of time. The length of the period varies with the tree species, as is shown in Table 1. Freezing of seeds to break the seed coat or pit is unnecessary. Freezing may, in fact, be injurious to some seeds.

Fresh seeds from mature fruits may be cleaned and planted immediately, especially in late summer or early fall (September and October). After-ripening processes then take place during the cool temperatures of fall and early winter. The seeds are spaced 1 to 3 inches apart in shallow trenches, 3 to 4 inches

TABLE 1. After-Ripening Requirements of Certain Fruit Tree Seeds. [1] [2]

Kind and Cultivar of Seed	Effective Temperature Degrees F.	Best Temperature Degrees F.	Time Required in Days	Remarks
APPLE, Domestic Cultivars: *(Malus sylvestris)* Delicious, Rome Beauty, Winesap	40° - 50°	40° - 41°	70 - 80	Seeds removed from fruit in cold storage will germinate following 30 days of after-ripening.
APRICOT, Domestic Cultivars: *(Prunus Armeniaca)*	40° - 50°	45°	60 - 70	
CHERRY, Mahaleb *(Prunus Mahaleb)*	33° - 50°	41°	90 - 100	Mazzard requires longest after-ripening period of stone fruit seeds.
Mazzard *(Prunus avium)*	33° - 50°	41°	120 - 140	
PEACH, Domestic Cultivars: *(Prunus persica)* Lovell, California cling	33° - 50°	45°	120 - 130	Lovell loses viability during dry storage; seed stored for more than 1 year gives low germination.
PEAR, Domestic Cultivars: *(Pyrus communis)* Bartlett, Beurre Hardy and Winter Nelis	33° - 41°	40°	60 - 90	Fresh seed taken out of fruit in cold storage will germinate after 30 days of after-ripening.
OTHER SPECIES:				
Sand Cherry *(Prunus Besseyi)*	33° - 50°	40°	60 - 90	
Nanking Cherry *(Prunus Tomentosum)*	33° - 50°	40°	60 - 75	
Mybrobalan Plum *(Prunus cerasifera)*	40° - 50°	40°	100 - 120	
Ackermann Plum *(Prunus domestica)*	40° - 50°	40°	120 - 130	

1 Adapted from Table 1, Bulletin 773, Propagating Fruit Trees, New York Agricultural Experiment Station.

2 Seed is best stored dry in sealed containers at a cool temperature. In after-ripening seed, one must keep in mind the approximate planting date in the spring. One determines when the after-ripening period should begin by counting back from this date the minimum number of days required for after-ripening.

deep, in the nursery row, and are covered with soil. If the soil type is one that forms a hard crust, it is better, first, to cover the seeds with a 1-to-2-inch layer of moist peat moss or sawdust, then finish covering with soil.

Before freezing temperatures occur in late fall, the planted rows should be mounded up with additional soil to protect the seeds over winter. The mound should be 6 to 8 inches high after settling. In early spring, the mound should be removed, leaving a layer of soil 1 to 2 inches thick over the seeds through which the sprouts can easily emerge.

All stone fruit seeds are best handled through fall planting. Apple, pear, and quince seeds may also be fall planted, although they are best handled as described in the next paragraph. Ground squirrels and other small animals may burrow in and eat fall-planted seeds. To protect the seeds, coarse-screen wire should be placed over and around each row of planted seeds before mounding up for the winter. The screen should be removed in the spring before germination takes place.

If fall planting is not possible, artificial conditions that will promote the after-ripening processes must be provided. Seeds may be prepared for after-ripening in the following manner:

1. Soak dried seeds in water for 10 to 12 hours before placing under conditions for after-ripening.
2. Place the soaked or fresh seeds in moist peat moss, sawdust, or other moisture-holding material; pack in metal cans, wood boxes, or other containers; cover the container but do not seal air tight.
3. Bury the packed containers in the ground over winter, preferably 10 to 12 inches deep in a sheltered area, or keep in a cool cellar. If kept in a cellar, container should be checked periodically and a small amount of water added if the contents begin to dry out.

   or

   Store the packed containers in a refrigerated room held at a constance temperature near 40° F., if such storage is available. Polyethylene bags may be used as the seed contained for this type of storage. Fold over the tops of the bags, tighten them securely to prevent moisture loss. Air can pass through the polyethylene film. Since this film is transparent, it is possible to inspect the seeds periodically without opening the bags. This method of storage is particularly useful with apple, pear, quince, and other small seeds.

As a result of even moisture and cool temperatures, chemical changes take place in the hard shells surrounding the seeds as well as within the seeds themselves. The period of after-ripening is definite for each species of fruit (Table 1). Chemical and physical changes result in the splitting of the outer hard shell and in germination of the seed. The seeds should be planted just before or as soon as the first sprouting begins. If this is not possible, they may be held in storage at 32° to 34° F. for one to three weeks without injury to the seeds or seedlings.

The outer shell or pit of peach, plum, and other stone fruit seeds may not always split open at the end of the conditioning period. Such pits may be carefully cracked, the seeds removed and viable ones planted. Often the seeds in such pits are decayed and shriveled and will not germinate, so these should be discarded.

Planting the Seeds and Care of Seedlings

Fruit tree seeds stored out-of-doors over winter should be planted early in the spring, since after-ripening processes are usually completed sometime in March.

The planting time of seeds can be partially determined by noting when after-ripening begins. Thus, if dry Mazzard cherry seeds are placed under after-ripening conditions between January 1 and 20, the seeds should be ready for planting in the nursery row between May 1 and 20. Table 1 gives the length of after-ripening periods for seeds of several fruit species.

The seedbed should be worked up in a manner similar to that for planting any other farm or garden seeds. It is desirable to plow under a winter cover crop of rye or similar grass. In most cases, broadcasting a mixed fertilizer before plowing under the cover crop hastens decay of the crop residue and release of nutrients to plant roots. A suitable application might be 300 pounds per acre of a 12-12-12 analysis fertilizer.

Tree fruit seeds should be spaced from 2 to 4 inches apart in shallow trenches and covered with 1 to 2 inches of a peat moss-soil mixture. On light soils, where crusting is not likely to occur, the peat moss may be omitted.

Seedlings of most tree fruit species should be large enough for budding to desired cultivars by late July or August or for grafting the following spring. In order to be large enough, they need to be well cared for during the entire growing season. Irrigation during dry periods can be very beneficial in producing large seedlings early. If the soil is rather low in fertility, or if fertilizer was not applied before plowig, an application of nitrogen may be made after the seedlings have made 3 to 4 inches of growth. Ammonium nitrate at 1½ to 2 pounds per 100 feet of row should produce the desired seedling growth.

PRODUCTION OF CLONAL ROOTSTOCKS

The most notable clones in fruit tree propagation are the East Malling (EM) and the Malling-Merton (MM) series of rootstocks used for controlling the size of the apple tree. The East Malling series originated about 1917 as selections from the Doucin and Paradise stocks then commonly used in England and Europe for apple tree propagation. The selections

were made at the Wye College Fruit Experiment Station at East Malling, England.

The Malling-Merton series originated at the John Innes Horticultural Institute at Merton and the East Malling Station, both in England. The MM stocks resulted from crosses of various East Malling clones and certain cultivars with the Northern Spy.

The separate clones or cultivars in each series are designated by numbers. The most common East Malling clones are: EM IX, EM VII, EM II and EM XIII, in the order of their effects in increasing tree size. EM XIII rootstocks produce standard size trees of cultivars worked on them. EM IX rootstocks produce the smallest size trees. A more recent addition to the East Malling Clonal rootstocks is the EM 26, which produces a tree somewhat larger than EM IX, but smaller than EM VII.

The common Malling-Merton clones now in use are MM 106, MM 104, MM 111, and MM 109. Trees on MM 106 are similar in size to those on EM VII, while MM 109 rootstocks produce nearly standard size trees. MM 104 and MM 111 produce tree sizes between these two.

Certain clonal cultivars of the quince may be propagated vegetatively, similar to the above apple clones. Few clonal rootstocks for stone fruits are available, although there is interest in developing such rootstocks for them. The only clonal stocks for stone fruits now available are two or three strains of Myrobalan plum.

Rooted shoots of desired EM and MM stocks are commercially available. These may be either whip grafted to desired cultivars, or lined out in nursery rows for budding later in the summer.

Mound Layering or Stooling

Certain tree species, cultivars, or clones may be multiplied by stooling or mound layering. This is true with the East Malling and Malling-Merton apple clones, most quince clones, and certain species of plums. A species or clone must have the genetic potential for the rooting of branches or shoots when covered with soil or other suitable rooting medium. Most cultivars of fruit trees do not have this potential.

The procedures described here are especially for layering the EM and MM clones of apple rootstocks, but may also apply to other fruit tree species, cultivars, or clones adapted to this propagation method.

The first step is to establish a stool bed for producing the shoots to be layered. For this it is necessary to get rooted shoots of the desired clone (Fig. 1). These are lined out in a nursery row, spaced 12 to 15 inches apart and set 7 to 9 inches deep, or about half the length of the shoots.

Planting is best done in a trench or furrow. It is gradually filled with soil as the new shoots develop. The trench should be completely filled 30 to 40 days after the beginning of spring growth. Filling in this manner assures good rooting along the stems. The trees are cultivated and permitted to grow unchecked during the first growing season. Each will become a stool or mother plant for the production of future rooted shoots.

Before growth begins the following spring, all the mother plants are cut back to one inch above the soil level. From two to five new shoots will develop from each mother plant during the second year. When these shoots reach 3 to 5 inches in height, the individual tree or row of trees is ridged up with loose soil or sawdust, enough to cover about two-thirds of the shoots' length. Ridging is repeated as the shoots grow taller, until the ridge is 10 to 12 inches high and some 24 to 30 inches wide. Three ridgings are usually sufficient and should be completed by the end of July.

The mounded shoots root readily during the summer and fall. Before growth begins the next spring, the mound is carefully removed, exposing the rooted shoots (Fig. 2). Each shoot is cut off as close as possible to the point at which it originated on the mother plant (Fig. 3). The rooted shoots become the rootstocks for grafting to desired cultivars (Fig. 4), or for lining out in nursery rows to be budded in late

Fig. 1 — Layered East Malling rootstock with well-developed roots. The rooted shoots are pruned off and used for grafting, or are lined out in nursery rows for budding in the summer. New shoots will arise from the base of the mother plant. These will then be mound layered to produce more rooted shoots for cultivar propagation.

Fig. 2 — Stool bed of East Malling rootstocks with mound of soil and sawdust being removed in preparation for cutting of the rooted shoots.

Fig. 3 — Rooted layers of East Malling rootstocks in the stool bed are being removed for further use in propagating desired cultivars.

summer (Fig. 5). They may also be used to establish new stool beds.

After removal of the shoots, the mother plant remains exposed until new shoots have again reached a height of 3 to 5 inches. The mounding procedure is repeated as during the previous summer.

Mother plants in a well-cared-for stool bed remain productive for 15 to 20 years. Layered stems of some clones that have not rooted can be cut off in late winter or early spring and made into hardwood cuttings as described in the next section.

Hardwood Cuttings

Most plants that root when mound layered will also root from cuttings. This is true of most East Malling and Malling-Merton apple rootstocks. Factors contributing to success in the rooting of cuttings include the condition of the wood from which cuttings are made and the time of planting them.

Hardwood cuttings are cut from healthy one-year-old dormant branches of from 3/16 to 1/4 inch in diameter and from 5 to 6 inches long. Cuttings from the basal end of a shoot will root more readily than those cut from the middle part. Tip portions of one-year shoots rarely root well, so should be discarded.

The cuttings can be made in late winter and stored in moist sawdust in a cold storage or cool cellar until planting time. During this time the basal ends will

Fig. 4 — Rooted East Malling layers are being sorted into groups of uniform size for further use. Those shoots which did not root may be made into hardwood cuttings for rooting and further propagation, as explained on pages 10 and 11.

Fig. 5 — Field of East Malling rooted shoots lined out in the spring for budding in August.

TABLE 2. Selected Rootstocks for Fruit Trees

Kind of Fruit	Standard Rootstocks	Special Rootstocks	Remarks
APPLE	Seedlings of Delicious, Rome Beauty, Winesap, Golden Delicious, and Jonathan	Dwarfing clones EM IX, EM 26, EM VII, EM II, MM 106, MM 104, MM III.	Buds or grafts should be inserted 12 to 18 inches from the ground on dwarfing rootstock. Clones of EM XIII and EM XVI will produce standards or near standard size trees with most cultivars.
PEAR	Seedlings of Bartlett, Beurre, Hardy, and Winter Nelis.	Dwarfing clone: Angers Quince EM Type A preferred, available as rooted cuttings. Other quince stocks may be used.	Since Bartlett and certain other cultivars are incompatible with quince, use an intermediate stock of Old Home between quince root and scion cultivar. Old Home is compatible with both Quince and Bartlett. Old Home may also be used as a blight resistant interstock for Bartlett and other blight susceptible cultivars.
PEACH and NECTARINE	Seedlings of Lovell preferred. Domestic cultivars may be used.	Red-leaved cultivars Dwarfing stocks: Seedlings of Western Sand Cherry; also of Nanking cherry and Beach plum.	Red-leaved cultivars used in the East make it easy to distinguish between seedling and budded cultivar in nursery rows. Some incompatability has been observed between the Red-leaved peach rootstock and some commercial cutivars.
PLUM and PRUNE	Seedlings of Myrobalan or cherry plum preferred for prune cultivars.	Nematode resistant rootstocks (seedlings): Nemaguard, Rancho Resistant and Okinawa. Available from California for trial use.	Superior selections of Myrobalan should be used when available for all cultivars. Avoid use of seedlings showing symptoms of "chlorotic fleck."
	Japanese cultivars· Marianna plum, in the west.	For American-Japanese hybrids: *Prunus Americana* Seedlings. Dwarfing stock: Western Sand cherry for prune cultivars.	Lovell peach seedlings can be used for plum and prune cultivars, but are inferior to plum seedlings.
CHERRY	Red tart cultivars: Mahaleb seedlings. Sweet cultivars: Mazzard seedlings	Dwarfing stock: Ground cherry *(Prunus fruticosa)*, but not always satisfactory	Select seed from trees free from cherry yellows and necrotic ring spot virsus diseases. These viruses can be transmitted through seeds.
APRICOT	Seedlings of Myrobalan or cherry plum, and of domestic cultivars.		Apricot seedlings preferred in East because of early fruiting habit and resistance to root-knot nematode.

callus, the first process necessary for root development. Early planting is essential for obtaining a high percentage of rooted cuttings. Early March, as soon as soil conditions will permit, is a good time to line out the cuttings. If planted later than April, rooting will be poor.

The cuttings are set 2 to 3 inches apart in shallow trenches. When set, the top bud should be just above soil level and the soil firmed well around the cutting.

Hardwood cuttings of quince and the clonal apple stocks root more readily than those of other tree fruits. In fact, it is nearly impossible to root cuttings made from cultivars of apples, peaches, pears, plums, and cherries. The Old Home pear cultivar, used as a blight-resistant interstock, can be propagated by hardwood cuttings if properly treated. Rooting can be increased by treating the basal ends of cuttings with indolebutyric acid and by placing the cuttings under mist to keep them continually damp.

Softwood Cuttings

Very few deciduous fruit plants are successfully propagated by softwood cuttings. Those that respond to this method of propagation are the Mahaleb cherry and selected clones of Myrobalan and European plums.

Soft shoots of new growth are selected for cuttings from June to late July. The shoots are cut into 4 to 6 inch lengths with the basal cut just below a bud or leaf and the upper cut just above a bud or leaf. The lowest leaf is removed for convenience in handling and inserting the cutting, but the others should be left on since they will aid in the rooting process. If the basal ends of cuttings are dipped into a growth regulator, such as indolebutyric acid, roots will often form quicker and more abundantly than if not treated. A growth regulator can be purchased from garden supply stores or horticultural supply firms.

The rooting medium may consist of sand, peat, vermiculite, or mixtures of one or more of these with soil. It is necessary to maintain moist conditions around the cuttings to prevent wilting of the leaves. The older practice consisted of planting the cuttings in propagation boxes covered with glass to maintain a high relative humidity in the box, and of watering frequently.

Newer methods take advantage of the fact that cuttings subjected to as much sunlight as feasible will root faster than if shaded. In modern propagation houses, softwood cuttings are grown under intermittent mist. This method of "mist propagation" permits the use of more sunlight during the rooting period and also keeps the cuttings moist at all times, making rooting possible in a higher percentage of cuttings.

TECHNIQUES OF CULTIVAR PROPAGATION

Budding and grafting techniques are used to properly insert the scion in a stock or rootstock. The scionwood should be selected from healthy trees, and, if possible, from indexed virus-free trees. This is particularly true of cherries, peaches, and apples in regard to specific virus diseases. Certan state agricultural experiment stations maintain trees free of virus that may be a source of scionwood.

There is less chance of mixing cultivars or of obtaining the wrong cultivar if budwood or scions are cut from true-to-name bearing trees. Proper labeling of scions and budsticks is essential for keeping cultivars properly identified.

Most fruit growers will want to purchase their trees from a nursery. However, they may wish to perpetuate a certain cultivar or multiply a cultivar for their own plantings or for the use of others.

BUDDING

All tree fruits grown in Ohio and surrounding states can be propagated by budding, the primary method of propagating all stone fruit cultivars. Budding is used primarily to propagate new trees of a cultivar, but may also be used in top working a tree of one cultivar to another (described later).

Time of Budding

In Ohio, the normal budding season begins in June with some species and may last until the latter part of September with other species. The best time for budding depends on the maturity of the buds to be transferred, and on the ease with which the bark "slips" or peels on the stock being budded. High rainfall and vigorous growth in the early growing season favors early development of favorable budding conditions. Some fruit species complete growth earlier than others, hence should be budded earlier. In general, the plant species complete their terminal growth in the following order, from early to late: Western Sand cherry *(Prunus besseyi)*, European plum *(Prunus domestica*, pear *(Pyrus communis)*, apple *(Malus sylvestris)*, Mazzard cherry *(Prunus avium)*, quince *(Cydonia oblonga)*, Myrobalan plum *(Prunus cerasifera)*, Mahaleb cherry *(Prunus mahaleb)*, and peach seedlings *(Prunus persica)*.

A few fruits may be "June budded," particularly peaches and to some extent apples. However, June budding is more common farther south where the growing season is longer than in Ohio. Budding is done on seedling stock in late May or June. Since dormant buds must be used, scionwood must be cut before buds break and must be stored under refrigeration (described under grafting). After the buds have united with the stock, the top of the stock is pruned off just above the inserted bud. The bud then grows and produces a tree ready for planting that fall or the following spring.

Selection of Budwood

Current season shoots of the desired cultivar provide the only source of budwood (Fig. 6). When col-

Fig. 6 — A healthy, vigorous shoot of current season's growth is selected for a "budstick." After being cut from the tree, the leaves are snipped off, leaving a short piece of petiole attached to the budstick.

lected, these shoots are referred to as "budsticks." Budwood should be selected which has an abundance of leaf buds rather than flower buds.

Vigorous shoots which have formed terminal buds will generally have suitable mature lateral buds. After the shoots are removed from the tree, the leaf blades are clipped off, leaving a short piece of the petiole attached to the shoot. Removing the leaf blades reduces moisture loss from the stick. Further drying out of the budsticks can be prevented by keeping them wrapped in moist cloth or in polyethylene bags with a small amount of moist paper towel. The budsticks are ready for immediate use, or they may be stored under refrigeration at about 34° F. until time for budding. If budsticks are to be shipped or mailed, they should be packed in polyethylene bags immediately upon cutting from the tree, but with no added moisture.

Plump, well-developed leaf buds from the mid-portion of the budstick are the most suitable. Buds from the base of the shoot and from the soft tip should be discarded if sufficient mid-portion buds are available.

Budding Technique

The technique most commonly used is shield or T-budding. The procedure is rather simple and may be mastered easily through practice. Shield budding is often employed when top working young trees, as well as in propagating cultivars on seedling or clonal rootstocks. Buds are normally inserted in shoots of the current season; however, budding into one-or two-year-old wood, as in the case of top working, can be quite successful.

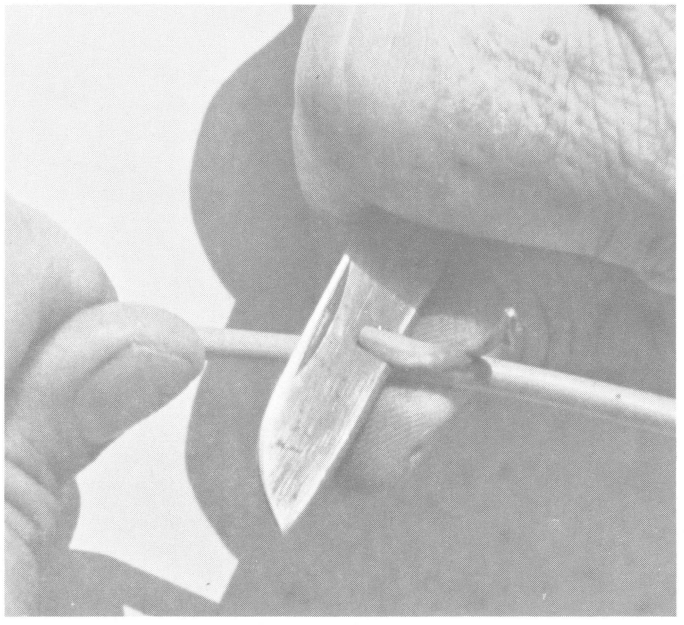


Fig. 7 — Cutting the shield bud from the bud stick begins about a half inch below the bud in the axle of the leaf petiole. The cut is made through the bark into the wood, then upward beneath the bud, coming out about a half inch above the bud. The thin section of bark and wood is called the "shield."

Shield Budding Procedure

The bud should be inserted in the base of seedling rootstocks at a point one to three inches from the ground. In apple clonal rootstocks used for dwarfing, the buds should be inserted from 12 to 18 inches above ground level. This will make possible deeper setting of the trees in permanent plantings. The steps in shield budding are as follows:

1. Cut the bud from a budstick in this manner: about a half inch below the bud begin cutting with a sharp blade (Fig. 7), cut into the wood slightly, then upward beneath the bud, coming out about a half inch above the bud. Thus, the bud and petiole stub are attached to a shield of bark and wood (Fig. 8). Some propagators prefer removing the sliver of wood from the bark (Fig. 9), others use the complete shield intact.

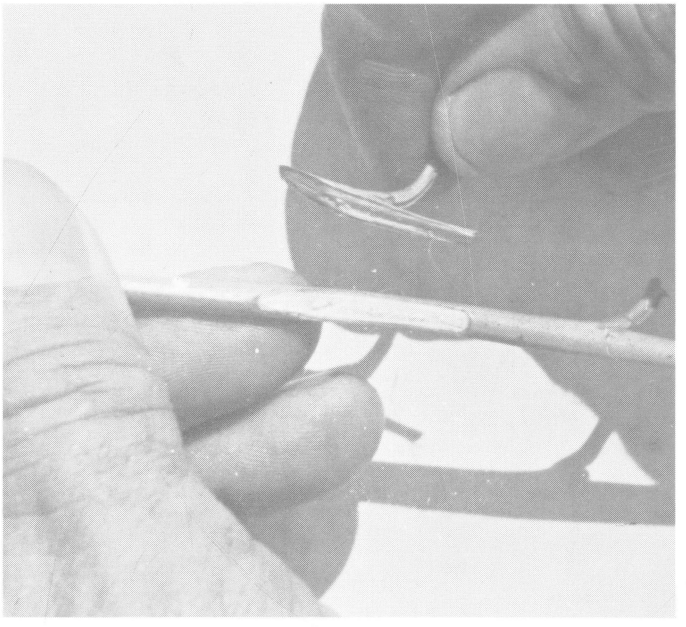


Fig. 8 — A shield bud cut from the budstick.

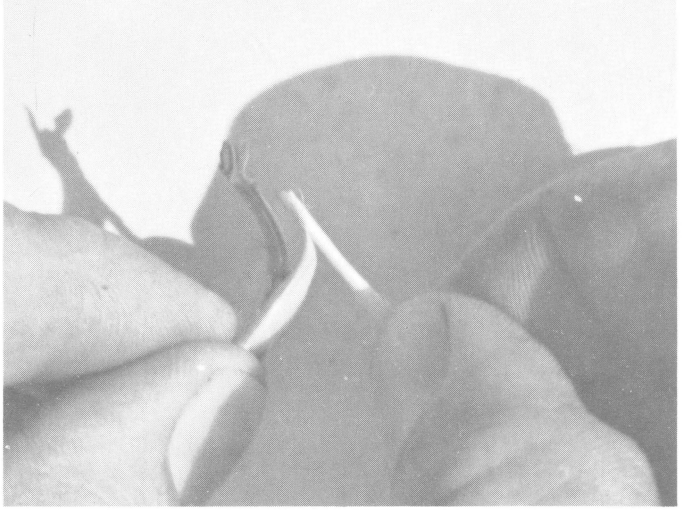


Fig. 9 — Removing the sliver of wood from the bark is preferred by some propagators. Others use the shield with wood intact.

Fig. 10 — (Left) A vertical cut through the bark is the first step in preparing the stock for budding. In the case of seedlings, the cuts are made 2 or 3 inches from the ground. With dwarfing stocks, the cuts are made higher on the trunk, 12 to 15 inches from the ground. **Fig. 11** — (Center) The horizontal cut is made across the top of the vertical cut, from 3/4 to 1 inch in length. **Fig. 12** — (Right) The bark slips well and can be gently loosened before inserting the bud.

2. Make a vertical cut through the bark of the stock about 1½ inches long (Fig. 10). At the top of this cut, make a horizontal cut (Fig. 11), thus forming the T-cut; then gently spread the bark from the wood (Fig. 12). The bark must slip easily in order for this to be done properly. The stock is now ready to receive the bud.
3. Insert the bud by grasping the petiole stub and gently pushing the shield downward beneath the bark of the T-cut in the stock (Fig. 13). If the bark of the shield extends above the upper cross cut, then cut it off even so the under surface of the shield fits snugly to the wood of the stock (Fig. 14).
4. Wrap the bud firmly to hold it in place until union is made with the stock. Special rubber budding strips are now widely used for this (Fig. 15).

To wrap with rubber stripping, start below the bud, cross the first turn to hold it in place, continue the wrap up to the bud, then above the bud but not over it, until all the cut surfaces are covered. Place the free end back under the last turn and pull it gently. When released, the stretched rubber strip will then secure the end as long as needed. In this way the wrap is smooth and no knots are needed. Three or four wraps both below and above the bud are usually sufficient (Fig. 16).

The size of strips varies from 3½ to 5 inches long and from 3/32 to 3/16 inch wide. The size of the stock being budded determines the size used. The smaller sizes are most commonly used in budding nursery stock. The rubber begins to "check" in about two weeks and usually rots off about four weeks after budding (Fig. 17). Occasionally, the strips may need to be cut, especially if the stock is growing very rapidly at the time of budding.

Care After Budding

The bud will remain dormant over winter (Fig. 18) except in rare instances of short growth in the fall. Buds that grow in the fall usually make poor trees or may be winter killed. In early spring, the stock should be pruned off to ½ to ¾ inch above the inserted bud (Fig. 20). In the case of apples and pears, the stocks may be cut off before growth begins. With stone fruits, however, it is best to delay cutting until new growth just begins. If cut while still dormant, stone fruit buds develop new growth slowly, and some may fail entirely. Mazzard

Fig. 13 — (Left) The shield bud is pushed gently into place beneath the bark flaps. **Fig. 14** — (Center) The shield bud is in place and ready for wrapping. **Fig. 15** — (Right) A rubber budding strip is used to wrap around the bud to hold it firmly in place.

Fig. 16 — (Left) The bud is completely wrapped, thus completing the final step in budding. **Fig. 17** — (Center) Three or four weeks later, the rubber strip begins to check and deteriorate. It usually breaks up before causing restriction of tree growth. If it does not, it should be clipped and removed. **Fig. 18** — (Right) The bud after rubber strip was removed, showing complete union with the stock. The dormant bud will grow the following spring.

TABLE 3. Properties of Selected

Clonal Rootstock	Propagation Method	Growth Effect On Scion Cultivar	Soil Requirements
EAST MALLING:			
EM VIII	Stooling	The most dwarfing; less than ¼ size of standard	Fertile, well-drained
EM IX	Stooling Hardwood cuttings Roots well	Very dwarfing; 1/4 to 1/3 size of standard	Fertile, well-drained
EM 26	Stooling Hardwood cuttings Roots well	Dwarfing; 1/3 to 1/2 size of standard; trees slightly larger than those on EM IX	Fertile, well-drained
EM VII	Stooling Hardwood cuttings Roots well	Moderately dwarfing; 1/2 to 2/3 size of standard	Will tolerate heavy soils; no special requirements
EM II	Stooling Hardwood cuttings Roots fairly well	Moderately to slightly dwarfing; 3/5 to 4/5 size of standard	Does well on both heavy and light soils
EM I	Stooling Hardwood cuttings Roots profusely	Slightly dwarfing; nearly size of standard	Fertile, well-drained, but of good moisture holding capacity.
EM XIII	Stooling Hardwood cuttings Roots profusely	Very slight dwarfing; nearly standard size; but depends on cultivar	Heavy soils with high water table
EM XVI	Stooling	Standard, little or no dwarfing	Fertile, well-drained
MALLING-MERTON:			
MM 106	Stooling Roots well	Moderately dwarfing; 1/2 to 2/3 size of standard; similiar to EM VII	Fertile, well-drained, but tolerant of high soil moisture
MM 111	Stooling Roots well	Moderately to slightly dwarfing; size similar to EM II	Fertile, well-drained
MM 104	Stooling Roots well	Slightly dwarfing, near size of EM I	Light, well-drained
MM 109	Stooling Roots well	Standard, little or no dwarfing; similar to EM XVI	Well-drained

Clonal Apple Rootstocks

Favorable Characteristics	Unfavorable Characteristics	Remarks
Induces early bearing; fruit matures a week earlier than on standard stock.	Brittle roots; tree needs support; roots subject to drought injury	Used primarily as an interstock and for home planting; since July buds will start to grow, bud in late August
Induces early bearing; withstands low temperatures	Brittle wood and roots; tree needs support	Use only as interstem to obtain dwarfing effects. Limited use.
Induces early bearing; does not sucker	Tree needs support	Stock is available free from major viruses. Promises to be widely used.
Fairly well-anchored; shoots free of laterals and spines; withstands low temperatures	Suckers badly, especially if planted shallow	A true semi-dwarfing stock; best used for strong growing cultivars that come into bearing late. Extensive use in commercial and home plantings.
Induces early bearing; well-anchored if set deep enough	Tender under severe winter temperatures	Use with cultivars that are not strong growers; trees may grow larger than desired in close plantings. Fairly limited use.
Induces early bearing on good soils; is well-anchored	Tender under severe winter temperatures; susceptible to collar rot	More dwarfing if grown in sandy soils. Limited use.
Tolerates wet soils; roots near the surface; well-anchored	Grows poorly or fails in dry soils; does not induce early bearing; variable effects with different cultivars	Influences fruit size favorably on bearing trees; good stock for Cortland and R. I. Greening. Very limited use.
Tolerant of high soil moisture	Susceptible to collar rot	Produces standard size trees. Of limited use.
Well-anchored, does not sucked badly; more tolerant of high soil moisture than MM 104; trees bear early	Few decided disadvantages have been reported although susceptible to mildew, and produces smaller tree on light soils	Tree size effects similar to EM VII; now preferred to EM VII by many. Stock is free from major viruses, such as stem pitting and chlorotic leaf spot. Has commercial possibilities.
Heavier bearing trees than those on EM II; well-anchored; more tolerant to drought than MM 104.	Produces fewer shoots in stool bed than some others; suckers slightly	Trees do not bear heavy as early as on MM 106. Limited use.
Well-anchored; early bearing	Sensitive to poorly drained soils	May be possible to grow trees on MM 104 without supporting. Has limited use.
Well-anchored, free from suckering; produces spreading trees with wide-angled crotches; resistant to collar rot; heavier bearing trees than on EM XVI	Does not tolerate poorly aerated or water-logged soils; root system somewhat one sided; not as well anchored as EM XVI	Value not proven.

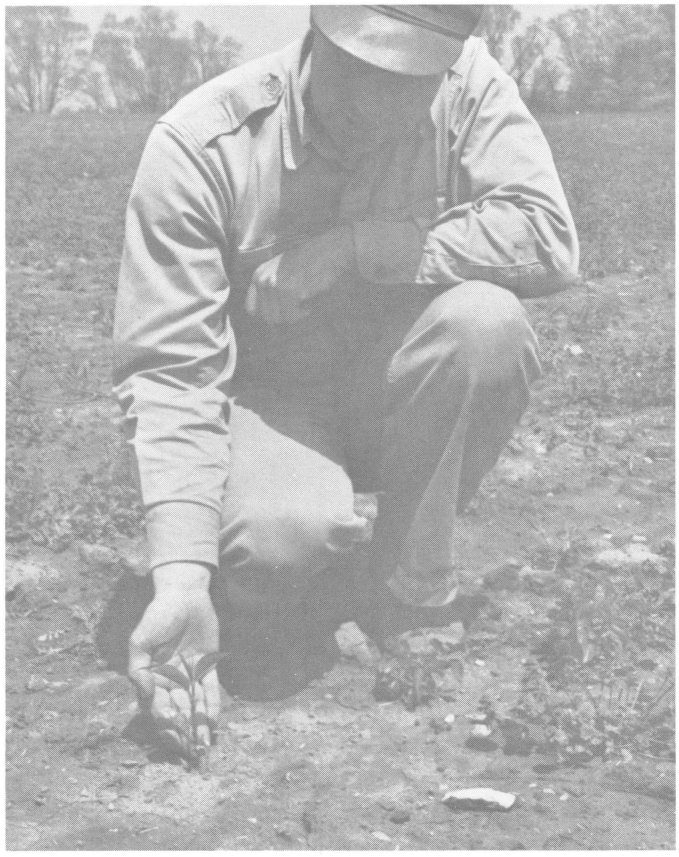


Fig. 19 — In the spring following budding, the top of the rootstock is pruned off just above the inserted bud.

Fig. 20 — Bud of the cultivar begins to grow into a budling that will be ready for planting in the fall or the following spring.

and Mahaleb cherry and peach seedlings are particularly sensitive to pre-growth cutting.

If a bud fails to take, the stock may be budded again. If too large for this, the top can be pruned off in the spring thus forcing a new shoot to develop near the ground. This shoot may then be budded at the proper time.

Any growth arising from the rootstock below the bud during the growing season should be rubbed or removed as soon as it appears.

Good foliage on the budling (the growth from the inserted bud) during the first season is very important. Cultivation, weed control, spraying to control disease and insects when necessary, and irrigation during prolonged dry periods can help maintain healthy foliage and produce maximum growth.

One-year-old budlings, if large enough, may be dug in the fall and planted in permanent locations. Peach and other stone fruit trees are normally large enough to be dug after one year's growth in the nursery (Fig. 21). Many apple and pear trees are also large enough the first year, however, it remains a common practice in some nurseries to grow these fruit trees two years before digging. Good one-year budlings are considered best for commercial orchard plantings (Figs. 22 and 23).

Fig. 21 — Budlings in the nursery row near the end of the first growing season. Such trees may be dug in the fall for storage or sale and planting, or they may be dug the following spring.

GRAFTING

Several grafting techniques have been perfected. The one to use depends on the conditions under which the grafting is to be done. **Whip grafting,** sometimes called bench grafting — the most common method in fruit tree propagation — is described under "Whip Grafting Techniques" on page 19.

Fig. 22 — A budded East Malling stock in the nursery row at the end of the first growing season. Note the smooth bud union and its position 12 to 15 inches from the soil level.

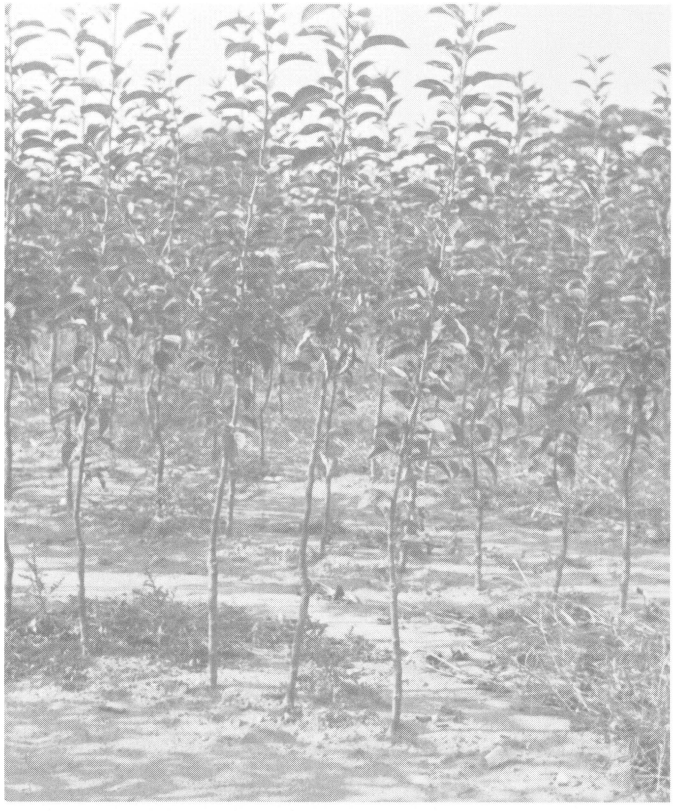


Fig. 23 — Apple trees in the nursery row that were budded the previous August. The cultivar is Golden Delicious on EM VII rootstock.

Cleft grafting is the technique most frequently used in top working a fruit tree and is explained under the section on top working. Other grafting techniques that may at times be used on fruit trees include **bark grafting, notch grafting, and side grafting.** In a broad sense, these may be considered as variations of either whip or cleft grafting.

Whatever the grafting technique used, it is necessary to match as perfectly as possible the cambium of the scion with the cambium of the stock. The stock and scion must line up in the same direction. When this is properly done with two compatible cultivars and the scion is held firmly in place without drying out before healing takes place, the union should be successful.

Grafting procedures as described in this bulletin may be successfully done with all the pome fruits, but is most widely used on apple trees. Grafting of stone fruit cultivars is not as successful, but satisfactory unions may be produced under favorable conditions.

Selecting and Storing Scion Wood

Only dormant wood can be used successfully as scions for grafting. Thus, scions must be cut while dormant and grafted immediately, or held under proper storage conditions until grafting can be done.

Terminal shoots or "water sprouts" of the previous season's growth make the most suitable scions. Shoot growth of 12 inches or more is better than shorter growth, and should have well-developed leaf buds. For whip grafting and top working, scions 1/4 to 3/8 inch in diameter work best.

Scion wood should be collected when temperatures are above freezing, and from healthy, virus-free trees in a vigorous state. If not used immediately, dormant scion wood may be stored in a manner that prevents drying of tissues and forcing of buds.

For storing, scions may be cut to suitable lengths, bundled, labeled as to variety, and packed in slightly moist peat or sawdust or wrapped in polyethlene sheets or bags with some moist material. If kept too moist, scions may mold and be useless for grafting. The storage temperature should be maintained between 32° and 40° F. Below freezing temperatures can result in injury to the scion wood.

Whip Grafting Techniques

This method works best when stock and scion are of similar diameter, preferably between 1/4 and 3/8 inch. Seedlings and rooted layers (Fig. 24) are whip grafted in late winter or early spring after they have been dug from the nursery row. Such grafting is generally done indoors and is commonly referred to as bench grafting.

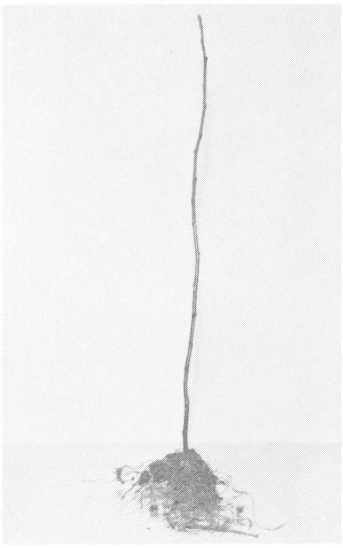


Fig. 24 — The rootstock used in whip grafting may be either a seedling or a rooted shoot of clone, as shown here. This is a shoot from a mound-layered EM VII (apple) stool bed.

Whip or bench grafted trees are stored in a manner similar to that of scion wood until time for planting out in the nursery row. During the storage period, the grafting wounds heal and callus, the first step in union of scion and stock.

Storage temperatures may range between 32° and 40° F., and the relative humidity should be maintained fairly high, as near 80 to 85 per cent as possible.

Whip grafting techniques can be easily mastered and are performed in the following manner:

1. Cut the scion from the mid-portion of a suitable dormant shoot, so that it has one or two good buds. A single shoot may yield from two to four suitable scions, depending on its length.
2. Make a sloping cut at the base of the scion from 1 to 1½ inches long (Fig. 25). The larger the scion, the longer will be the cut. On the sloping cut surface, about one-third the distance from the tip, begin another cut nearly parallel to the first (Fig. 26), making it from ½ to ¾ inch long.

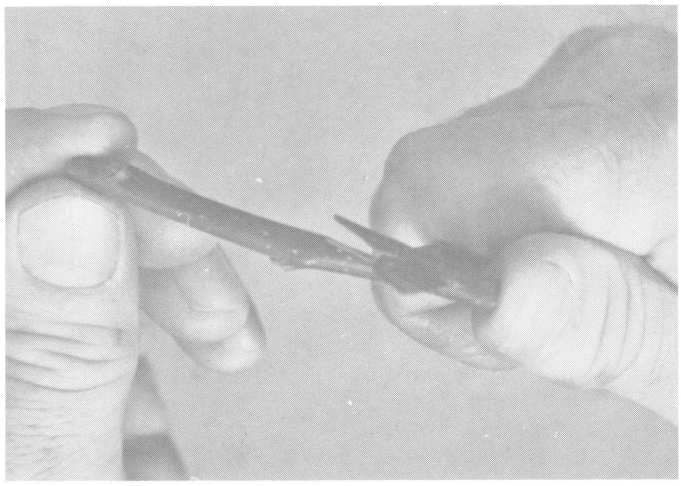


Fig. 25 — In whip grafting, the scion is cut so that it contains two good leaf buds. The lower cut, as shown, is sloping with a surface of 1 to 1½ inches long.

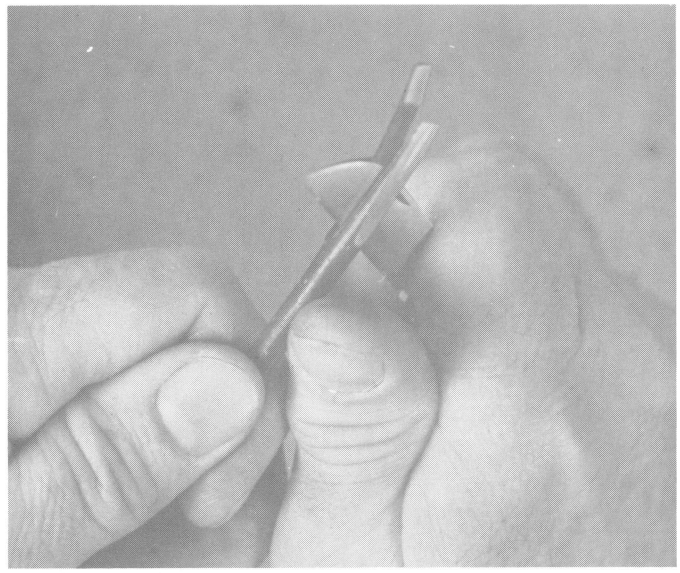


Fig. 26 — About one-third the distance from the scion's lower end to the end of the cut, a second cut is made into the center of the scion and nearly parallel with the first one.

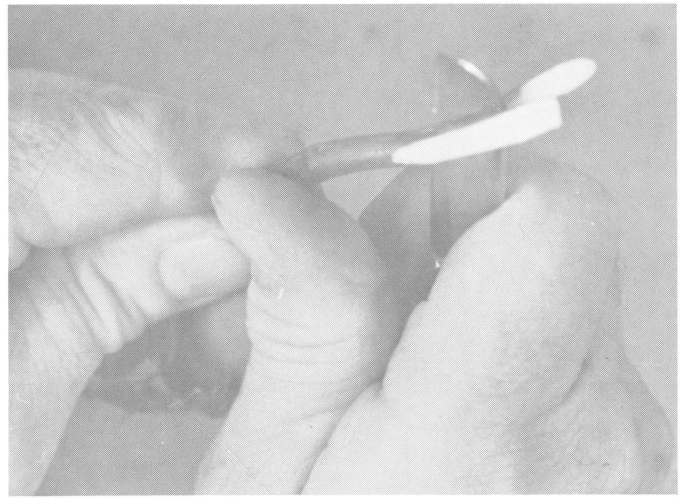


Fig. 27 — The upper end of the rootstock is cut and shaped in the same way as the lower end of the scion.

Fig. 28 — The scion (right) is slipped on the rootstock (left) in the tongue-and-groove fashion. The cambium of the scion must match as perfectly as possible that of the stock, at least along one side.

3. Prepare the end of the stock to be grafted in the same manner as the scion (Fig. 27).
4. Fit the scion and stock together tightly so that the cambiums of the cut surfaces match perfectly on at least one side (Fig. 28). If stock and scion are of equal diameters, both sides will match. The toe of the scion should just come to the heel of the stock.
5. Tie the graft firmly by wrapping it with a rubber strip, (Fig. 29 and 30) grafting tape, raffia, or other suitable material. If the wrapping material does not decay and break as growth takes place, it should be cut about a month after growth begins.
6. Wax the graft unions completely to prevent drying of tissues (Fig. 31). The cut surface on the scion tips should also be waxed (Fig. 32). (See section on waxes and tools for grafting).

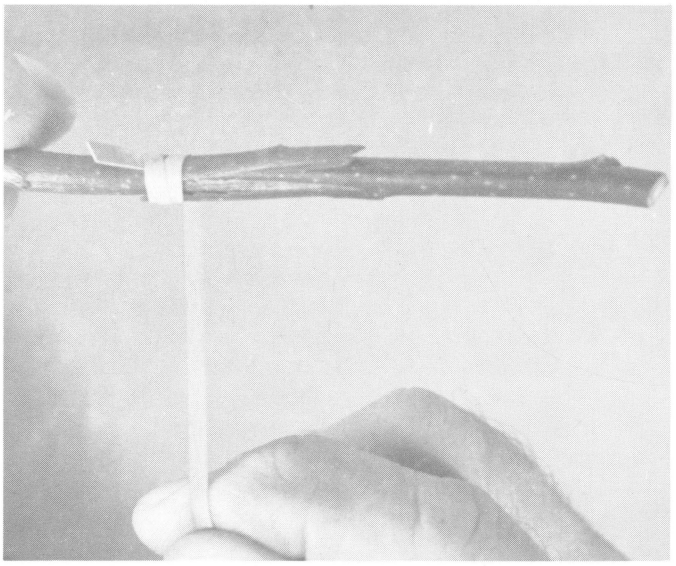


Fig. 29 — A special rubber strip (budding strip) can be used to wrap the graft union.

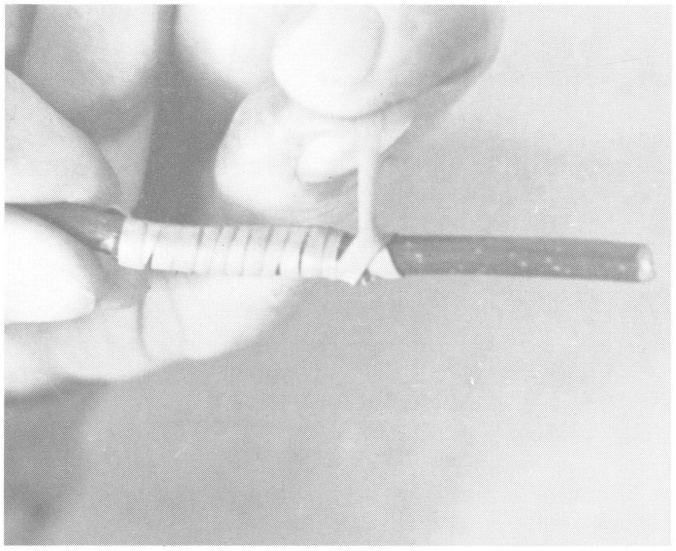


Fig. 30 — The graft union is completely wrapped, thus holding the scion in place until growth is complete.

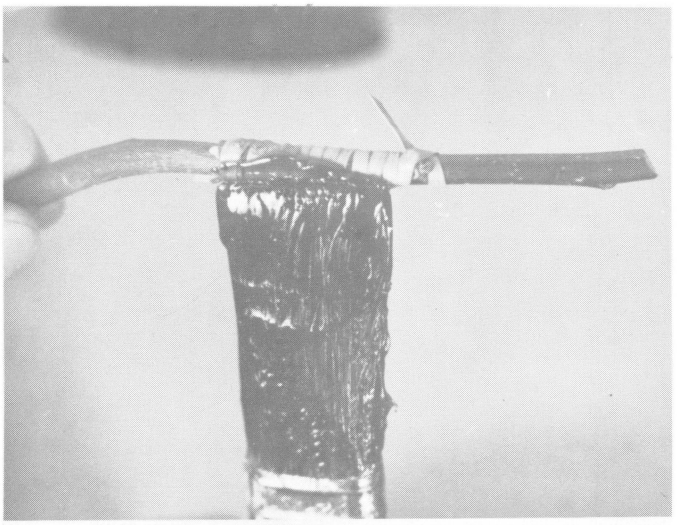


Fig. 31 — Asphalt compound or grafting wax is applied to keep scion and tissues from drying out. The graft union is completely covered. Buds on the scion should not be covered.

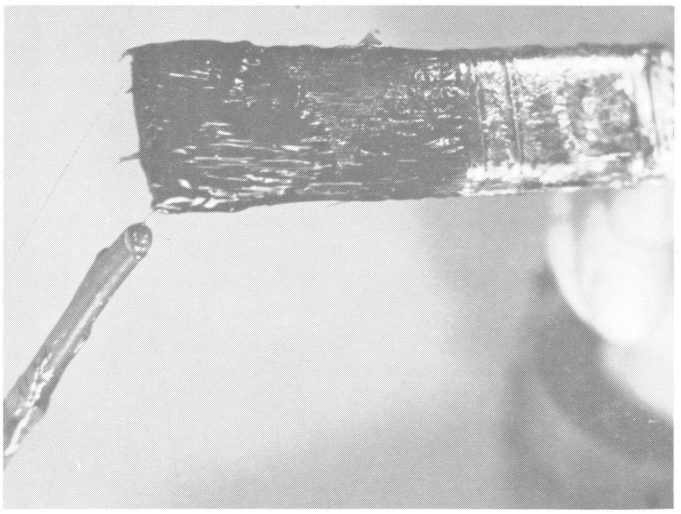


Fig. 32 — The tip of the scion is also waxed.

Care After Grafting

Seedlings or clonal stocks that have been whip grafted are generally planted in nursery rows. The trees are spaced about a foot apart in the row, and the rows are made four feet apart.

If both buds on the scion start growing, the one with the shortest growth should be pruned off soon after growth begins. This leaves a single shoot to grow into the new tree (Fig. 33). Competing shoots that may arise from the stock below the graft union should be removed as soon as observed during the first growing season. These can be rubbed or snapped off by hand when they are under 5 or 6 inches in length.

The soil around the trees and between rows should be shallow cultivated and hoed as needed to control grass and weeds during the growing season. Spraying may be necessary occasionally to keep leaf-feeding insects and foliage diseases under control. Irri-

Fig 33 — (Left) A grafted rootstock in the nursery row. Upper bud of the scion has started satisfactory growth. Growth from the lower bud has been removed. **Fig. 34** — (Center) Growth from a graft at the end of the first season in the nursery row. The tree, a one-year whip, will be ready for transplanting in the fall or the following spring. **Fig. 35** — (Right) A two-year-old apple tree with the interstem piece of EM IX, the enlarged segment used to induce dwarfing. The root system is that of an apple seedling and the top scion cultivar is that of Jonathan.

gation during prolonged dry periods will help maintain constant growth and the production of suitable size trees.

After growing in the nursery row one season, most grafted trees are ready for permanent planting that fall or the following spring (Fig. 34). Smaller trees may be left in the nursery row or transplanted to another nursery row for a second year's growth before being moved to permanent plantings. One-year trees, or whips, of suitable size are most satisfactory for commercial orchard plantings. Labeling trees with metal, plastic, or other long-lasting labels aids in keeping nursery stock properly identified.

Interstock Grafting — Double Worked Trees

It is occasionally desirable to insert a special stem piece between a rootstock and the top scion cultivar (Fig. 35), largely to bring about certain desired effects upon the growth of the scion.

Certain dwarfing effects can be accomplished by following this procedure. A stem piece of the dwarfing stock such as EM IX, EM VIII, or EM 26 is grafted to a seedling or other suitable rootstock. Then at the terminal end of this stem piece is grafted the scion cultivar for its fruit production. The dwarfing effect is not as great as if the cultivar were grafted directly onto the dwarfing rootstock. However, there is some evidence that the tree may develop a somewhat larger root system and may not need to be supported as when a cultivar is grafted directly onto the dwarfing rootstock.

In double-worked trees, two graft unions are employed, and one or both may become points of weakness that will result in tree breakage. There is some evidence that certain apple cultivars, such as Stayman, are not entirely compatible with all dwarfing interstocks, especially EM IX and EM VIII. These stock should be avoided when propagating Stayman.

Interstem grafting may be accomplished by using one of two techniques. First, bench or whip grafting may be used. A 6-to 8-inch scion of the dwarfing stock is grafted to a one-year seedling. The grafted stock is then lined out in the nursery row in early spring. In mid-summer, the desired apple cultivar is budded onto the scion at least 5 to 6 inches above the previous graft union. The tree is then handled as any other budded tree in the nursery row. This method requires two years to produce a tree suitable for planting.

In the second technique, buds from the dwarfing stock are inserted in the seedling rootstock while it is growing in the nursery row, at the most suitable time in mid-summer. In mid-summer of the following year, the desired cultivar is then budded onto the resulting whip growing from the inserted dwarf stock bud. The cultivar bud is inserted 5 to 6 inches above the previous bud union. This technique requires three growing seasons to produce a plantable tree. This disadvantage, however, may be outweighed when large numbers of trees are propagated, since less scion wood is needed than in the previous method.

The double-budding technique is particularly adaptable to the propagation of dwarf pear trees. Some cultivars, such as Bartlett, do not make strong unions with the quince dwarfing rootstock. This can be over-

come by first budding a cultivar to the quince stock that is compatible with it, such as the blight-resistant Old Home. Then the following year, the desired cultivar can be budded onto the interstem cultivar, which is compatible with both the rootstock and the cultivar desired for its fruit.

TOP WORKING PROCEDURE

It is sometimes necessary or desirable to change the top cultivar of a tree. This may be done while the tree is still growing in the nursery row or after it has grown one or more years in its permanent location. The process of grafting scions of the desired cultivar onto the framework branches of the tree is termed "top working" or "top grafting." Through top working, a tree containing two or more cultivars may be produced. Such trees are excellent for home plantings.

All methods of graftage may be employed in top working. Budding and whip grafting (Fig. 36) are frequently used on young trees that are one to four years of age, and where branches are small enough to accomodate these methods. In the case of peaches and other stone fruits, budding is universally used. With older apple and pear trees, another graftage technique is usually followed, namely, "cleft grafting." Branches that are more than an inch in diameter lend themselves especially well to this technique.

Trees up to 4 or 5 years of age (Fig. 37) may be top worked entirely at one time. Larger trees should have the operation spread over two or possibly three years, top working one-half or one-third of the top each year. It is impractical and unprofitable to top work large mature trees, especially after 10 to 12 years of growth.

The number of scions that can be inserted in any given tree depends largely on its size, and whether the tree is completely worked over in one year (Fig. 38). Obviously, the older or larger the tree, the greater the number of scions that will be needed. When a young tree, 3 or 4 years of age, is top worked, it may require from 1 to 3 or 4 scions on each main scaffold branch, or from 12 to 20 per tree. Older and larger trees may require from 50 to 100 scions per tree. On larger trees, it may be necessary to set the grafts farther from the main trunk than on younger ones because that is where the most suitable diameter wood is located.

A few small branches should be left on the tree framework the first year, especially on larger trees.

Fig. 36 — A two-year-old apple tree that has been top worked by whip grafting. The four main scaffolds and the central leader were grafted to a single cultivar at the same time. The trunk and framework branches could be that of a particular hardy cultivar, or they could carry resistance to the fireblight disease.

Fig. 37 — An apple tree of this size can still be satisfactorily top worked and have the top changed to another cultivar.

Fig. 38 — The same apple tree as in Fig. 37 after top working by cleft grafting. Seven main scaffold branches were grafted to a new cultivar. Five branches of the original tree remain to provide some shade for the grafts and tree framework. These will be pruned off the following spring.

Fig. 40 — The same tree after all of the original tree was pruned out, leaving only the grafted branches.

These grow and provide shading of the grafts. By the second year, the new scions will have made enough growth to shade unions and stub areas (Fig. 39). The growth from the original tree framework can then be pruned off (Figs. 40 and 41). From then on, all new growth from the original tree should be pruned off annually, thus permitting maximum growth of the new scion cultivar and hastening its time of bearing fruit.

Fig. 39 — The top-worked apple tree in Fig. 38 the following spring.

Fig. 41 — The same tree after some of the grafts were thinned out. The tree is off to a good start and may bear a few fruits the following year.

One use of top working is in the production of pear trees with a fire blight-resistant framework. Here the practice is to use seedling pear as the rootstock, or quince for dwarf trees, and to bud or graft the Old Home cultivar onto it in the nursery row. This cultivar has a high degree of blight resistance. Following the second growing season of the Old Home scion, it is top worked to the desired cultivar, such as Bartlett. In this way, if the cultivar blights and kills one or more branches, new shoots from the Old Home framework can be rebudded or grafted, thus preventing loss of the entire tree.

Top working can be used to develop a winter-hardy intermediate stock between the rootstock and the scion cultivar. With the apple, a hardy cultivar is budded or grafted to a suitable rootstock, such as a seedling or one of the Malling or Malling-Merton clones. This scion cultivar grows for one to three years or until a suitable number of scaffold branches have developed for top working. The scaffold branches are in turn budded or grafted to the cultivar desired for production. This practice has made possible the growing of certain apple cultivars in northern climates that otherwise would experience severe low temperature injury to the trunk and body of the tree. Some of the hardy intermediate stock cultivars of apples that may be used successfully are Antonovka Shafran, Columbia, and Kulon Kitaika. These are cultivars of foreign origin, hence scion wood or trees of these are not readily available. Scion wood of these may be obtained from certain agricultural experiment stations in this country.

Particular factors to be considered in top working are:

1. Branches to be top worked must be properly selected as to size, position on the trunk, and number. In the case of cleft grafting, an upright branch of 1 to 2 inches in diameter will give the best results.
2. Those parts of the tree being grafted should not be exposed to sunscald. Neither should scions be placed where they will be heavily shaded during the growing season.
3. The new cultivar must be compatable with the one being top worked. There are few problems of incompatability between cultivars of a given species. There may be problems when a cultivar of one species is top worked on a cultivar of another species, such as European plum on Japanese plum, peach on apricot, apple on pear, or pear on quince.
4. A sound graft union must be made, regardless of technique used.
5. If budding is used in top working, buds may be inserted in one-or two-year-old wood as well as in shoots of the current season.

CLEFT GRAFTING

The cleft graft is made by inserting a scion into a carefully made split in the stub remaining after cutting off a branch, or in the case of a small tree, the trunk. Such grafts can be successfully made on stocks that are between 1 and 2 inches in diameter. The grafting can be done in late winter or after growth starts. Results are best when it is done just before spring growth begins, but dormant scions must be used.

The procedure in cleft grafting is fairly simple, but does require a special tool to do it properly and efficiently. The steps in making a cleft graft are as follows:

1. Prepare the stock in this manner: saw off squarely the branch or trunk, then split carefully with the grafting tool and mallet (Fig. 42). The split should be across the center of the stub and extend downward 1½ to 2 inches,

Fig. 42 — In cleft grafting, the grafting tool is used to split the branch stub for receiving the scions.

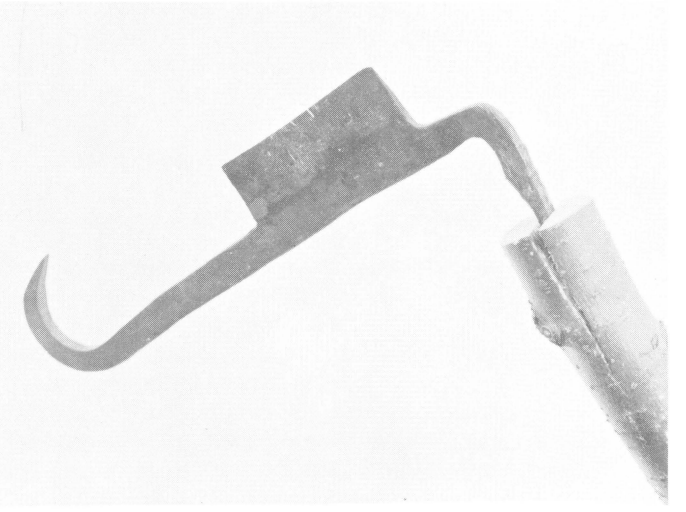


Fig. 43 — Chisel end of the grafting tool holds the split open while the scions are inserted.

depending on the size of the stock and the scion to be used. The split, or cleft, is opened with the chisel end of the grafting tool (Fig. 43) ready for inserting the scion. Stocks of large diameter may have a scion placed in each end of the split.

2. Cut the scion in the shape of a wedge at the basal end (Fig. 44). One side of the wedge should be slightly narrower than the other. Each cut should be made about 1½ inches long with a single stroke of the knife and tapered evenly towards the end. If the scion is not cut in this shape, it will make contact with the stock only at the thickest portion. The other end of the scion is cut off so that 2 or 3 buds remain above the wedge cuts.

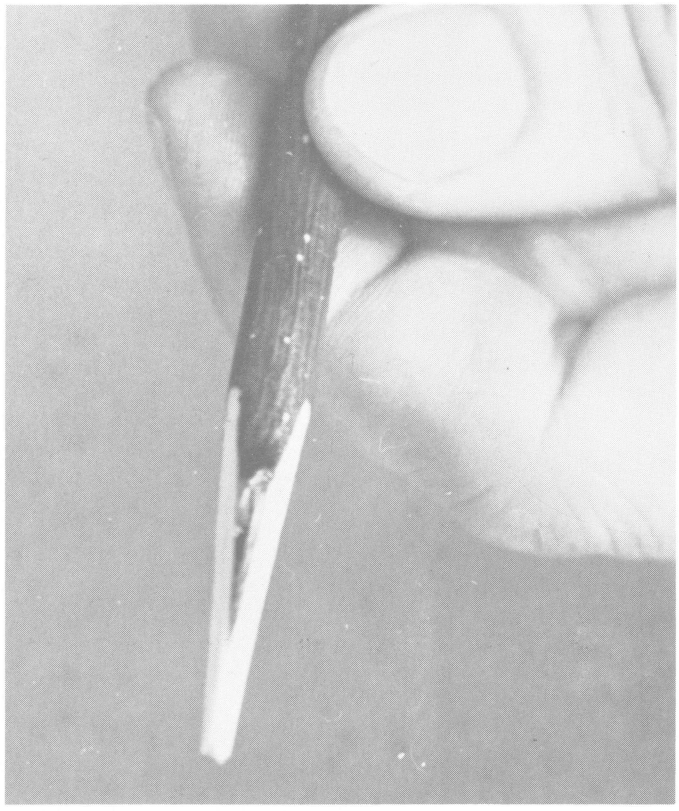


Fig. 44 — The scion for cleft grafting is cut in a wedge shape on the lower end. One side of the wedge is slightly thicker than the other. The thin edge goes to the inside of the stock, and the thick edge to the outside where its cambium will match that of the stock.

3. Insert the scion in the side of the opened cleft of the stock, with the narrow side towards the center (Fig. 45). Push it gently into position so the scion cambium matches the stock cambium. If a small scion is placed in a large stock, the matching is not as easily done since the thickness of bark tissues will vary considerably between the stock and scion. If necessary, slant the scion slightly so that its cambium will contact at least a part of the stock cambium. Larger stocks will take two scions (Fig. 46). If this is done, the point of contact should begin about ¼ inch below the shoulder of the stock. Once the scion is in place, remove the grafting tool. Pressure of the stock will hold it in position.

Fig. 45 — The scions are inserted, one at each end of the split or cleft. Cambium of the scion must match as perfectly as possible that of the stock if union and growth are to result.

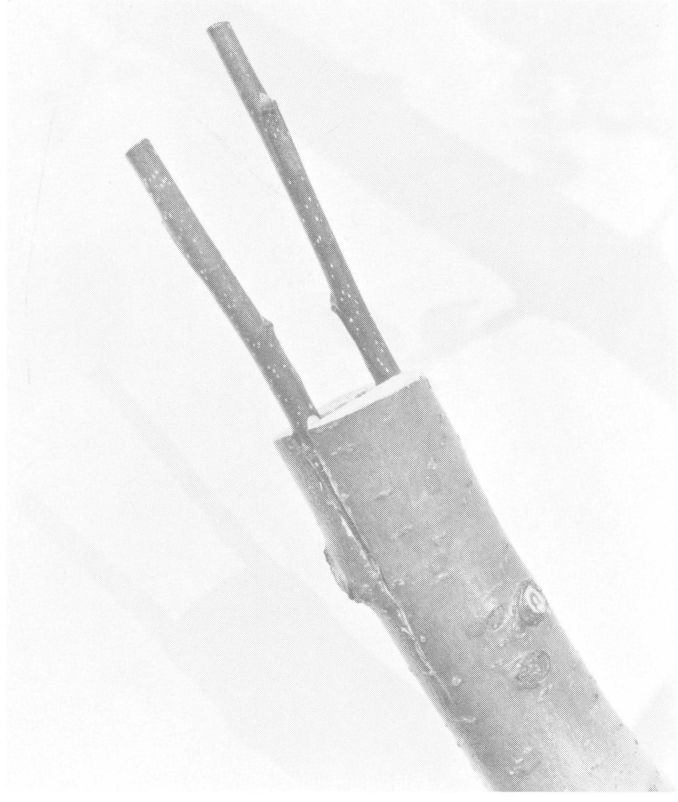


Fig. 46 — The two scions in place and the grafting tool removed.

4. Coat all cut surfaces including the scion tip (Figs. 47 and 48) with wax or other protective materials. Complete coverage is necessary, especially in the cleft and on the sides of the stock. It's a good practice to check the grafts periodically during the growing season to make sure that the wax covering remains intact. Re-wax if necessary, but do not cover buds. If the cut surface of stock or scion begins to dry out, then union will not take place. Some attention must be given to the grafts after they begin to grow. It is best to allow all growth from scions to develop during the first season. Shoots that begin to grow very vigorously may be pinched back in early June to induce branching. After the first growing season, light pruning will need to be done.

Fig. 47 — Grafting wax (or asphalt coating) is applied to the scion tip. This prevents drying of the tissues and hastens union of stock and scion.

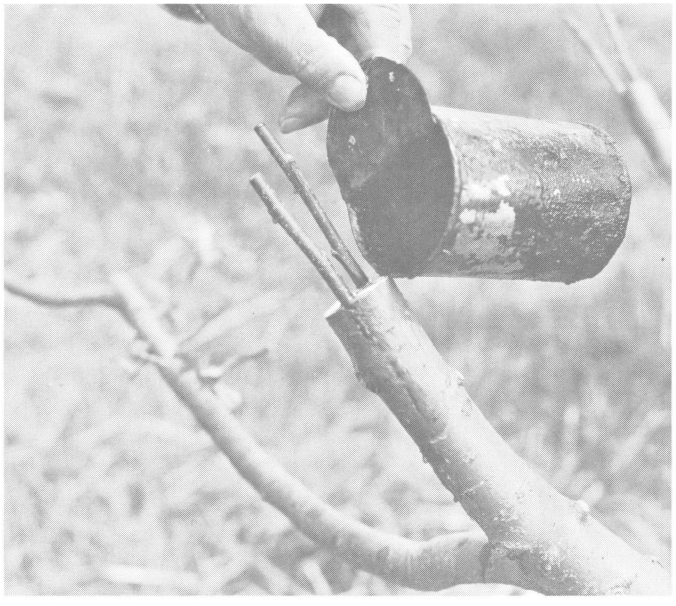


Fig. 48 — Grafting wax is being applied to the cut surfaces of the stock to prevent drying of tissues. If scion and stock tissues dry, union may not take place.

BARK GRAFTING

The bark graft may be used in place of the cleft graft in top working, and especially in making grafts on rather large diameter stubs. Some grafters prefer this method because it does not involve splitting the stub, and a higher percentage of "take" is achieved.

Bark grafting is done in the spring at the time when the bark separates easily from the wood. The scion is prepared with a single cut about 1½ inches long on one side of the basal end, thus making this portion of the scion wedge-shaped (Fig. 49-A). A short, sloping cut, about ½ inch long, is made on the opposite side of the longer cut, forming a beveled end on the scion. A shoulder is cut at the upper end of the longer cut, so the scion will fit over the top of the stock stub.

The branch is cut off as in cleft grafting, then a section of bark is removed from the top of the stub with the exact dimensions of the beveled end of the scion.

The prepared scion is held in place on the outside of the bark. With a sharp knife, the bark is cut to correspond with the length and width of the wedge-shaped end of the scion (Fig. 49-B). The lower end of the scion, with the long bevel towards the stock, is then pushed under the bark between the two cuts, thus separating the bark from the wood (Fig. 49-C) as the scion is pushed downward (Fig. 49-D). The lifted bark is then cut off even with the top of the short bevel on the outside of the scion. The scion is tacked with two small brads or nails to hold it firmly to the stock. All cut surfaces of the graft union should be thoroughly waxed, as well as the tip of the scion. While some wax on the buds will do no harm, heavy wax coatings should be avoided.

If the stock is large enough, additional scions can be placed in a single stub. These should be spaced 2 to 4 inches apart.

There are variations to bark grafting, but all use the same basic principal. Some prefer leaving the stock bark intact and tacking it with the scion to the stock. There are also variations in shaping the beveled end of the scion.

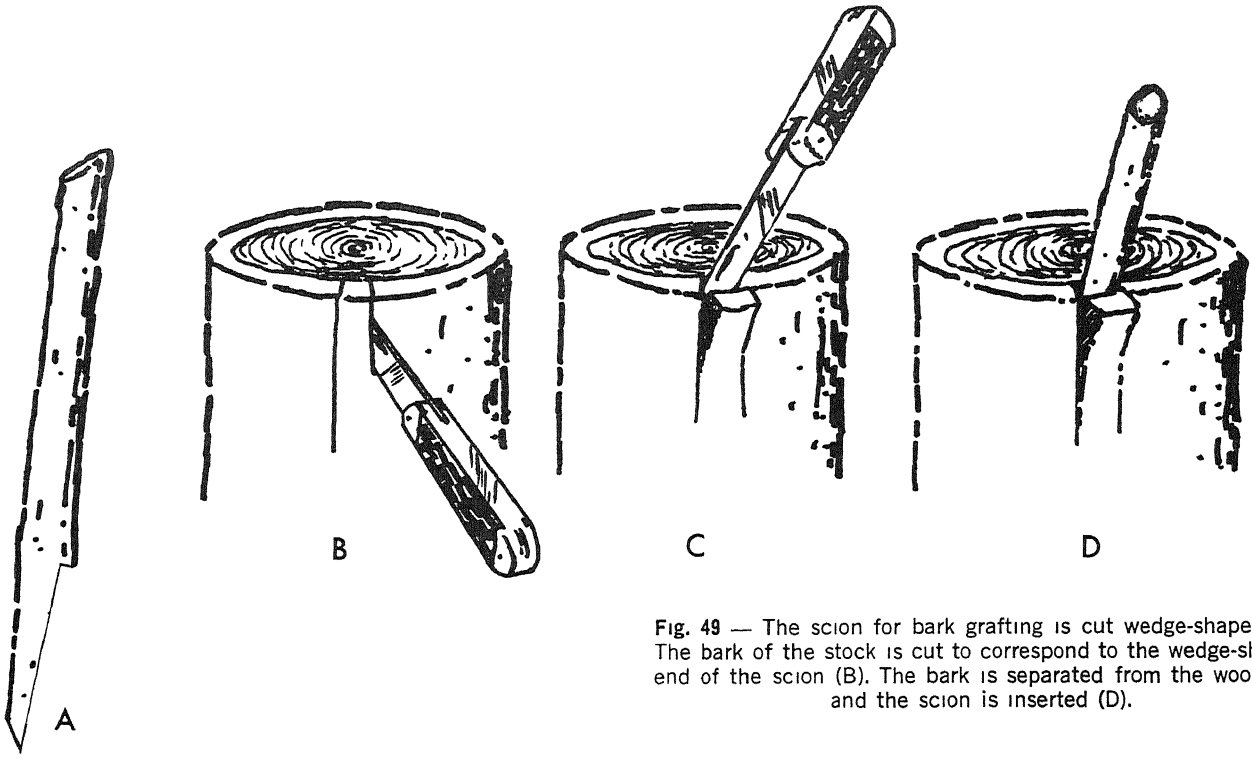


Fig. 49 — The scion for bark grafting is cut wedge-shaped (A) The bark of the stock is cut to correspond to the wedge-shaped end of the scion (B). The bark is separated from the wood (C), and the scion is inserted (D).

SPECIAL APPLICATIONS OF GRAFTING TECHNIQUES

BRIDGE GRAFTING

Bridge grafting is primarily used to bridge over a dead or wounded area on a tree trunk or main scaffold branch. It is frequently used to repair trees damaged by meadow mice feeding on the base of the tree or by rabbits feeding on the trunk and lower branches of young trees. Apple and pear trees can be most effectively bridge grafted.

Bridge grafting can be done easily when the bark slips well, which is usually after spring growth begins. It may be done anytime up to bloom or even later, providing dormant scions are available. The procedure is rather time-consuming and some practice is necessary in order to develop the skills that lead to successful bridge grafts.

In preparing the area to be bridged over, carefully remove all dead and injured bark tissue, exposing healthy, live bark on all edges (Fig. 50-B). Vertical cuts 2 to 4 inches long are made through the bark where the ends of the scions are to be inserted. These cuts are spaced about 2 inches apart and opposite each other across the injured area.

Dormant water sprouts of suitable lengths make the best scions. Each sprout is cut so that it is slightly longer than the distance between the extremities of the two bark cuts opposite each other. Each end is then shaped into a wedge with beveled points (Fig. 50-A), in the same manner as described for bark grafting, except that no shoulder is left.

The bark along one of the slits is gently lifted with a knife blade or sharpened stick, the end of the scion slid under the bark and into place with the cut surface adjacent to the wood of the tree. The same procedure is followed with the other end of the scion, then both ends are tacked down with one or two small brads. Since the scion was slightly longer than the area bridged, it will have a slight bow (Fig. 50-D). This puts tension on the ends of the scion, thus helping to hold it in place. Scions are spaced about 2 inches apart (Fig. 50-D).

When all the scions needed to bridge the area are in place, the graft unions and all exposed live bark surfaces are covered with a coat of wax or asphalt compound.

As in bark grafting, there are also variations in the bridge grafting technique. Shaping of the beveled ends of the scions may be varied, especially to fit different types of cuts in the bark on the tree being grafted. In the case of mature trees and bark which doesn't slip easily, it is necessary to cut a section of bark completely from the area where the scion is to fit. This must be done carefully so the beveled surface of the scion fits snugly into the area from which the bark was removed. The scions are tacked in as previously described.

If buds on the inserted scions begin to grow during the first year, the young shoots should be rubbed off as soon as noticed. If growth is permitted to continue, the graft unions may be weakened or even fail completely. Since young bridge grafts are subject to rodent injury, they should be protected with hardware cloth, aluminum mesh foil, or other suitable coverings as soon as the grafting is completed.

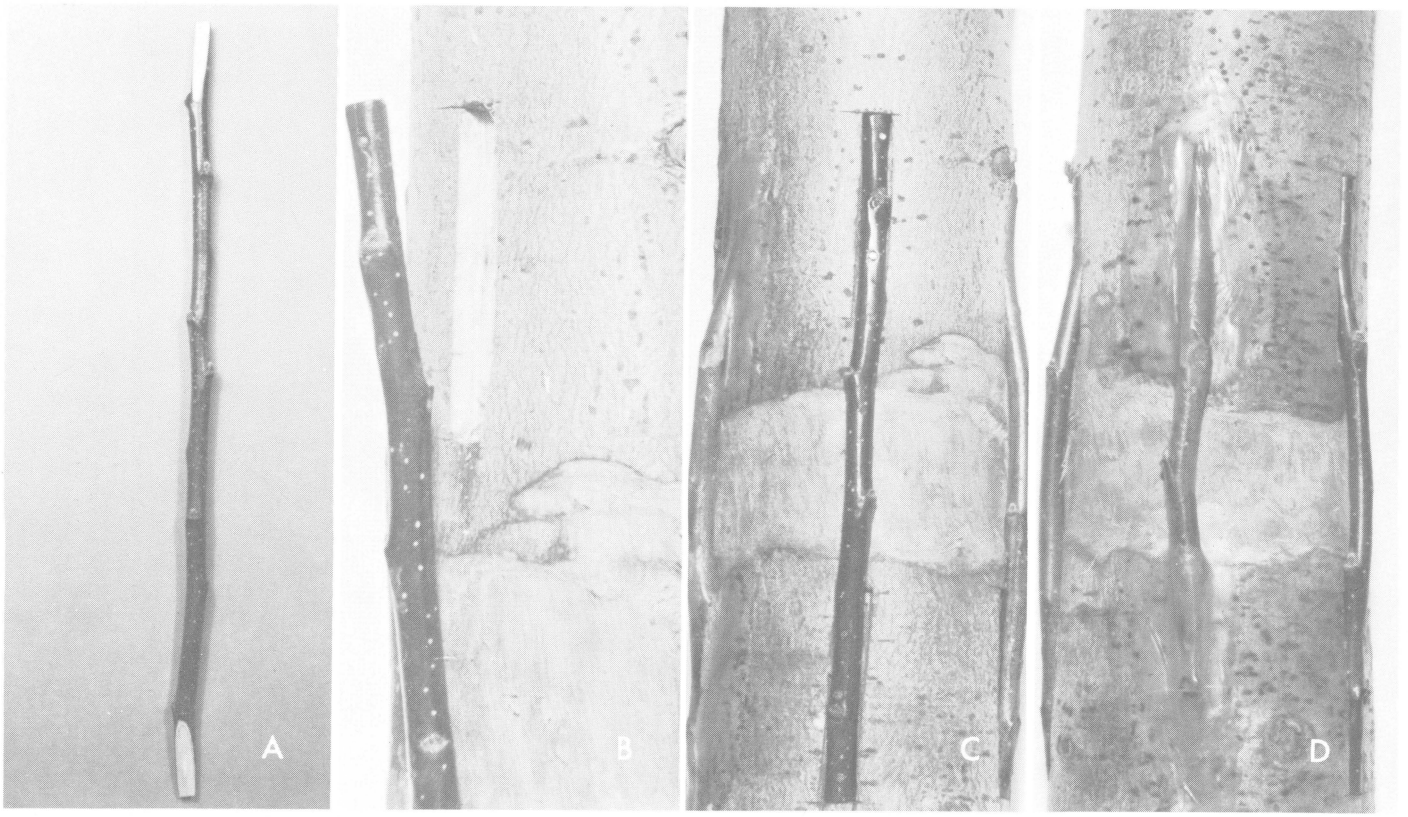


Fig. 50 — Bridge grafting procedure: (A) Scion is cut the proper length and both ends beveled for insertion. (B) Section of bark is cut from healthy tissue above the wound area and of the same dimensions as the beveled end of the scion. A similar cut is made below the wound area to be bridged. (C) Scion in place, bridging the wound area on the tree trunk. Two small brads hold each end in place. (D) Ends of inserted scion after properly waxed. Also note the slight bow in the two adjacent scions which helps to hold them firmly in place.

INARCHING

Occasionally, extensive injury to the lower trunk and root system occurs, making the wounded area unsatisfactory for bridge grafting. In such cases the process of **inarching** the ends of trunks or branches of seedling trees into the live bark area above the injury of the trunk can bring about satisfactory tree recovery. As with bridge grafting, this method is usually successful only with apple and pear trees.

One-year-old seedlings are planted around the tree and as close to the trunk as possible. In planting, the young trees should be slanted towards the trunk of the injured tree. The seedlings should be spaced 6 to 8 inches apart around the tree, using a sufficient number to bridge over the injured area properly.

Dead and injured bark is first cut away from the injured trunk, exposing healthy bark tissues. The ends of the seedlings then may be prepared and inserted beneath the tree bark in the same way as in bridge grafting (Fig. 51). If necessary to bridge over an extended dead area, the end of the seedling may be bark grafted to the trunk or main scaffold branch higher up on the tree (Figs. 52 and 53). The technique is the same as bark grafting. Such grafts should be protected from rodent injury as in the case of bridge grafting.

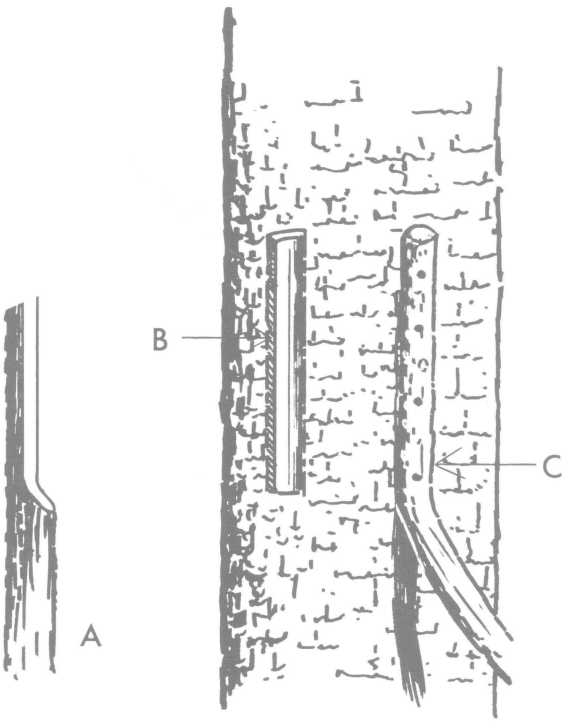


Fig. 51 — Inarching procedure: (A) end of seedling with slice cut from the end of the seedling on the side nearest the injured tree; (B) slot cut in the bark of the tree trunk to match the cut end of the seedling; (C) end of the seedling inlaid in the bark slot and held with small brads.

Fig. 52 — Inarching with seedling apple trees saved this tree which was girdled by meadow mice at ground level. Ends of the seedlings were inlaid in the healthy bark of the tree trunk, and coated with a wound dressing.

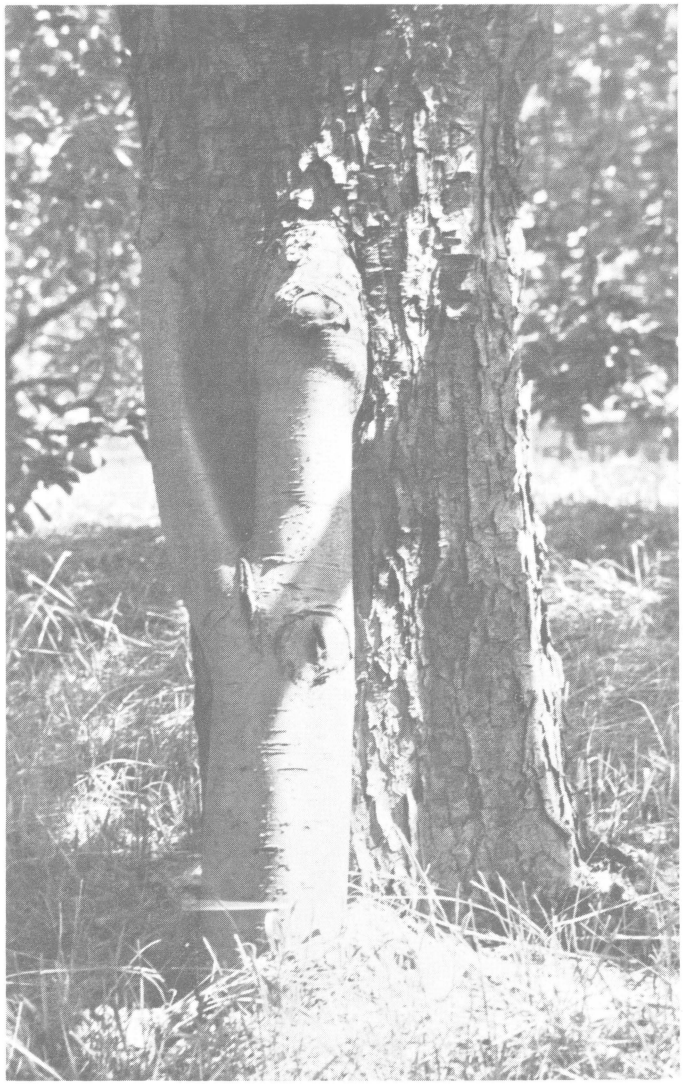


Fig. 53 — The base of this apple tree was partially girdled by meadow mice several years ago. By inarching a young apple seedling into the trunk, the tree was saved and its productive life extended indefinitely.

GRAFTING TOOLS AND PROTECTIVE COATINGS

TOOLS

The tools and equipment (Fig. 54) normally used in budding and grafting can be purchased from garden and orchard supply stores, or from nurseries and special dealers. The essential tools are pruning shears, knives, saws, cleft grafting tool, mallet or suitable hammer, sharpening stones, and a supply of No. 18 brads for bridge grafting.

The grafting tool (clefter) used in cleft grafting can be made in the farm workshop by shaping a hard piece of steel to the illustrated form. The appropriate edges are then sharpened as illustrated. The cutting edge may be either straight or concave. A concave cutting edge makes smooth edges for receiving the scions by cutting the bark before the wood can split and tear the bark away. Most tools used in cleft grafting have straight edges and when used carefully will split the branch little beyond the desired limit.

When hard waxes are used for coating graft unions, a heater is needed to melt the wax and keep it thin enough for application. A small unit equipped with an alcohol burner, as illustrated, is adequate.

Budding and grafting knives should be made of good steel and kept razor sharp at all times. A dull knife can be the cause of poor healing and poor union of scion with stock. A grafting knife should have a straight-edged blade; a budding knife with the edge curving upward at the point works best. It is the sharp curved end of the blade that is used most to cut the bark for insertion of the buds.

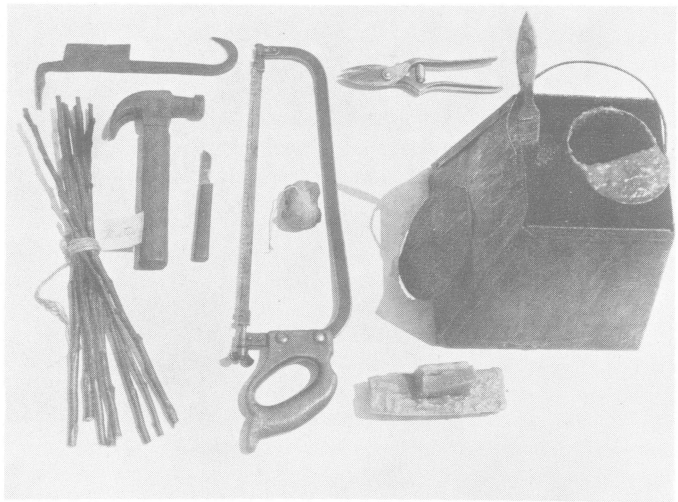


Fig. 54 — Tools and supplies needed in grafting: scion wood (cultivar labeled), cleft grafting tool, hammer, grafting knife, pruning saw, pruning shears, wax, container for wax, brush, and a unit for heating wax to melt it while it is being used. (An alcohol lamp provides the heat in this unit.)

PROTECTIVE COATINGS, WAXES, AND SUPPLIES

All grafting wounds, except buddings, need to be covered with a protective coating immediately after completion of the graft. Characteristics of a suitable grafting wax or other protective coating are:

1. Retains the moisture in the wood and excludes air and fungi from the wounds.
2. Contains no material that would injure live tissue in the strength recommended for use.
3. Has sufficient body to fill cracks easily and is convenient to handle.
4. Is elastic enough to accommodate itself to changes in dimension of stock and scion resulting from growth.
5. Neither cracks in cold weather nor runs in hot weather.
6. Is relatively inexpensive.

Asphalt-water emulsion dressings are now widely used as protective coatings on graft unions, other cut surfaces or injuries on trees. Such compounds are readily available from garden supply stores and orchard supply firms, and are generally preferred to grafting waxes.

Asphalt emulsions have certain advantages over hot waxes, or even hand waxes. They can be thinned with water to the consistency desired for a particular use. They can be applied cold, and they crack less readily in sudden changes of temperature than waxes. They adhere well to the surface of fresh wounds such as those made in grafting.

Most of the older grafting waxes require heating to bring them to the proper consistency. Some waxes are pliable at hand temperature and are called hand or soft waxes, requiring no other source of heat. These, however, are no longer recommended.

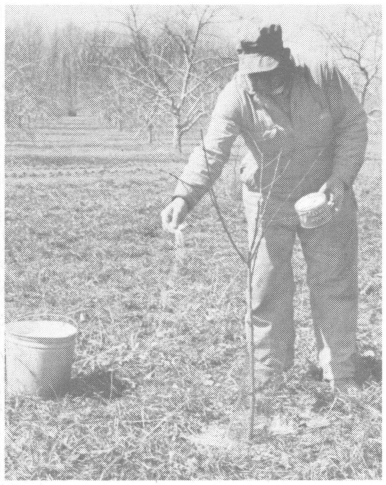
For those who wish to prepare their own grafting waxes, the following formula and information are presented.

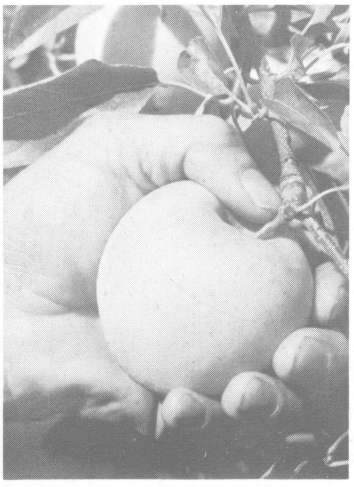
A standard **brush wax** consists of the following ingredients: rosin — 5 parts, beeswax — 1 part, linseed oil — ¼ part, lamp black or powdered charcoal — ½ part.

First, slowly melt the rosin then add the beeswax. When both are completely melted add the linseed oil and stir. When mixed well, remove from the heat and add the lamp black or powdered charcoal a little at a time while stirring slowly. Continue stirring until it has a smooth consistency and is a uniform black color. The lampblack or charcoal will make the wax tougher and more pliable. Before use, brush wax must be melted to a consistency that can be brushed on easily yet cool quickly and will not run.

Any wound coating should be inspected periodically to make sure it is still intact. If it has broken away or "checked" badily before healing is complete, a new coating should be applied over the old one.

Brushes, tools, or hands soiled with asphalt may be easily cleaned with gasoline or kerosene before washing with soap and water.





PROPAGATION TECHNIQUES . . . These are the basis of the modern commercial tree fruit industry. Only through these *techniques can trees of known growth* and fruiting characteristics be reproduced and cultivars maintained. The ready availability and use of trees with known desirable characteristics offer the grower the opportunity of gaining the highest returns from his managerial skills.